Caltech

CALIFORNIA INSTITUTE OF TECHNOLOGY

DESIGN GUIDELINES
v. 5.5

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TABLE OF CONTENTS

TABLE OF CONTENTS 2
DEFINITIONS 10
GENERAL REQUIREMENTS 11
PROJECT DELIVERY 24
DIVISION 01 – GENERAL REQUIREMENTS 26
Section 01 43 00 — Quality Assurance 26
Section 01 43 39 – Mock-ups 27
Section 01 43 39.1 – Interior Mock-ups 28
Section 01 45 00 — Quality Control 34
Section 01 56 00 — Temporary Barriers and Enclosures 35
Section 01 58 00 — Project Identification 37
Section 01 78 00 — Closeout Submittals 37
Section 01 81 00 — Sustainable Design Requirement Renewable Energy 39
DIVISION 02 – EXISTING CONDITIONS 40
Section 02 41 00 - Demolition 40
Section 02 41 16 - Structure Demolition 41
Section 02 41 19 - Selective Demolition 41
Section 02 80 00 - Facility Remediation 41
Section 02 82 00 - Asbestos Remediation 42
Section 02 83 00 - Lead Remediation 43
Section 02 87 13 - Mold Remediation 44
DIVISION 03 – CONCRETE 46
Section 03 30 00 – Cast-In-Place Concrete 46
DIVISION 04 – MASONRY 48
Section 04 22 00 – Concrete Masonry Unit 48
DIVISION 05 – METALS 50
Not Used 50
DIVISION 06 – WOODS, PLASTICS, AND COMPOSITES 51
Not Used 51
Section 07 50 00 – Roofing and Waterproofing General Requirements 52
Section 07 13 00 – Pre-Applied Sheet Membrane Waterproofing 53
Section 07 13 26 – Post Applied Self Adhering Sheet Membrane Waterproofing 56
Section 07 14 16 – Cold Fluid–Applied Waterproofing 58

Section 07 18 00 – Traffic Coating **61**
Section 07 26 16 – Below-Grade Vapor Retarders **61**
Section 07 52 00 – Modified Bituminous Membrane Roofing **62**
Section 07 54 19 – Polyvinyl Chloride Roofing **64**
Section 07 56 00 – Fluid Applied Roofing **66**
Section 07 57 13 – Sprayed Polyurethane Foam Roofing **68**
Section 07 60 00 – Flashing and Sheet Metal **72**
Section 07 84 00 – Firestopping **72**
DIVISION 08 – OPENINGS 74
Section 08 14 00 – Wood Doors **74**
Section 08 33 43 – Overhead Coiling Smoke Curtains **74**
Section 08 44 00 – Curtain wall and Glazed Assemblies **75**
Section 08 50 00 – Windows **75**
Section 08 71 00 – Door Hardware **76**
DIVISION 09 – FINISHES 88
Section 09 22 00 – Non-Structural Metal Framing **88**
Section 09 23 00 – Gypsum Plastering **90**
Section 09 24 23 – Portland Cement Stucco **91**
Section 09 29 00 – Gypsum Board **92**
Section 09 30 00 – Tiling **93**
Section 09 51 00 – Acoustical Panel Ceilings **94**
Section 09 65 00 – Resilient Flooring **97**
Section 09 67 23 – Resinous Flooring **97**
Section 09 68 13 – Carpet Tile **99**
Section 09 69 00 – Access Flooring **99**
Section 09 90 00 – Painting and Coating **100**
DIVISION 10 – SPECIALTIES 102
Section 10 11 16 – Markerboards **102**
Section 10 14 00 – Signage **102**
Section 10 21 00 – Toilet Compartments **110**
Section 10 26 00 – Wall and Door Protection **110**
Section 10 28 13 – Toilet Accessories **111**
DIVISION 11 – EQUIPMENT 113
Section 11 13 00 – Loading Dock Equipment **113**
Section 11 20 00 – Institutional Equipment **113**

Section 11 30 00 – Residential Equipment 113
Section 11 52 00 – Audio-Visual Equipment 114
Section 11 53 00 – Laboratory Equipment 114
Section 11 53 13 – Laboratory Fume Hoods 114
Section 11 53 13.15 Exhaust Hood 118
Section 11 53 13.30 Biosafety Cabinet 118
Section 11 81 29 – Facility Fall Protection Equipment 119
Section 11 82 23 – Recycling Equipment 119
DIVISION 12 – FURNISHINGS 120
Section 12 24 00 – Window Shades 120
Section 12 32 00 – Manufactured Wood Casework 120
Section 12 35 53 – Laboratory Casework 122
Section 12 35 53.13 – Metal Laboratory Casework 140
Section 12 91 00 – Interior Waste and Recycling Receptacles 143
DIVISION 13 – SPECIAL CONSTRUCTION 144
Section 13 21 00 – Controlled Environment Rooms (Cold/Warm Room) 144
Section 13 21 13 – Clean Rooms 149
DIVISION 14 – CONVEYING EQUIPMENT 150
Section 14 20 00 – Elevators 150
14 20 01 — Passenger Elevators: 150
14 20 02 — Laboratory and Service Elevators 152
14 20 03 — Parking Structure Elevators 152
14 20 04 — Freight Elevators 152
DIVISION 21 – FIRE SUPPRESSION SYSTEMS 154
Section 21 00 00 – Fire Suppression System Control Valve Selection Table 154
Section 21 05 00 – Common Work Results for Fire Suppression 154
DIVISION 22 – PLUMBING 162
Section 22 00 00 – Plumbing Systems 162
Section 22 05 00 – General Requirements for Plumbing Systems 164
22 05 13 Common Motor Requirements for Plumbing Equipment: 164
22 05 23 General-Duty Valves for Plumbing Piping: 165
22 05 29 Hangers and Supports for Plumbing Piping and Equipment: 165
22 05 48 Vibration and Seismic Controls for Plumbing Piping and Equipment: 165
22 05 53 Identification for Plumbing Piping and Equipment: 165
Section 22 07 00 – Plumbing Insulation 166

22 07 00 General 166
22 07 19 Plumbing Piping Insulation 166
Section 22 10 00 — Plumbing Piping 167
22 11 16 Domestic and Industrial Water Piping 167
22 11 17 Alternate Water Systems for Reuse: 168
22 11 19 Water Piping Specialties 169
22 11 23 Water Booster Pumps 170
22 13 00 Sanitary Waste and Vent System: 170
22 14 00 Storm Drainage System: 171
22 16 00 Natural Gas System: 172
22 17 00 Fuel Oil System: 172
Section 22 30 00 – Plumbing Equipment 172
22 33 00 Electric Domestic and Industrial Water Heaters 172
22 34 00 Gas-Fired Domestic and Industrial Water Heaters 173
22 35 00 Domestic and Industrial Water Heat Exchangers 174
Section 22 40 00 —Plumbing Fixtures 175
22 40 00 Plumbing Fixtures 175
Section 22 60 00 — Laboratory Plumbing Systems 175
22 61 00 Compressed Air Systems for Laboratory Facilities: 175
22 62 00 Vacuum for Laboratory Facilities 175
22 63 00 Gas Systems for Laboratory Facilities 176
22 66 53 Acid Waste and Vent System: 177
DIVISION 23 – HEATING, VENTILATING & AIR CONDITIONING (HVAC) 179
Section 23 00 00 – HVAC Systems 179
Section 23 05 00 – General Requirements for HVAC Systems 185
23 05 13 Common Motor Requirements for HVAC Equipment: 185
23 05 16 Expansion Fittings and Loops for HVAC Piping: 187
23 05 19 Meters and Gauges for HVAC Piping: 187
23 05 23 General-Duty Valves for HVAC Piping: 189
23 05 29 Hangers and Supports for HVAC Piping and Equipment: 190
23 05 48 Vibration and Seismic Controls for HVAC Ducts and Equipment: 190
23 05 53 Identification for HVAC Piping and Equipment: 191
23 05 93 Testing, Adjusting, and Balancing (TAB) for HVAC: 191
Section 23 07 00 – HVAC Insulation 193
23 07 00 General: 193

23 07 13 Duct Insulation: 193
23 07 16 HVAC Equipment Insulation: 194
23 07 19 HVAC Piping Insulation: 194
23 07 20 HVAC Insulation Jackets: 195
Section 23 20 00 — HVAC Piping and Pumps 196
23 21 13 Hydronic Piping: 196
23 21 16 Hydronic Specialties: 197
23 21 23 Hydronic Pumps: 198
23 22 13 Steam and Condensate Piping: 198
23 22 16 – Steam and Condensate Specialties: 199
23 22 23 Steam Condensate Pumps / Receivers: 199
23 25 00 HVAC Water Treatment: 199
Section 23 30 00 – HVAC Air Distribution 200
23 31 00 HVAC Ducts and Casings: 200
23 33 00 Air Duct Accessories: 203
23 34 00 HVAC Fans: 206
23 36 00 Air Terminal Units: 207
23 37 00 Air Outlets and Inlets: 210
23 38 00 Ventilation Hoods: 210
Section 23 40 00 – HVAC Air Cleaning Devices 211
23 40 00 HVAC Air Filters and Cleaning Devices: 211
23 44 00 UVC Lights 212
Section 23 50 00 – Central Heating Equipment 214
23 57 00 Heat Exchangers for HVAC 214
Section 23 70 00 – Central HVAC Equipment 215
23 73 00 Indoor Central-Station Air-Handling Units – Custom-Packaged, Outdoor, Central-Station Air-Handling Units 215
Section 23 80 00 – Decentralized HVAC Equipment 217
23 81 23 Computer Room Air Conditioners 217
23 82 16 Air Coils 217
23 82 19 Fan Coil Units: 218
23 84 00 Humidifiers 219
SECTION 23 09 00 – BUILDING AUTOMATION SYSTEMS REQUIREMENTS 220
Section 23 09 00 – Instrumentation and Controls for HVAC Systems 220
DDC Alarm Table 228

DIVISION 26 – ELECTRICAL 239
Section 26 00 00 – Electrical Systems 239
Section 26 05 00 – General Requirements for Electrical Systems 249
Section 26 10 00 – Medium Voltage Electrical Distribution 260
Section 26 20 00 – Low Voltage Electrical Distribution 261
Section 26 30 00 – Electrical Power Generating and Storing Equipment 271
Section 26 50 00 – Lighting 284
DIVISION 27 – COMMUNICATIONS 287
Section 27 20 00 – Voice and Data Communications 287
Section 27 40 00 – Audio / Visual Systems 304
DIVISION 28 – ELECTRONIC SAFETY AND SECURITY 307
Section 28 10 00 – Access Control and Video Surveillance 307
Section 28 46 00 – Fire Detection and Alarm 307
DIVISION 31 – EARTHWORK 309
Section 31 10 00 – Site Clearing 309
Section 31 11 00 Clearing and Grubbing 309
31 13 00 Selective Tree and Shrub Removal and Trimming 309
31 14 00 Earth Stripping and Stockpiling 309
Section 31 20 00 – Earth Moving 309
Section 31 22 00 Grading 309
31 23 00 Site Utilities, Excavation and Fill 309
DIVISION 32 – EXTERIOR IMPROVEMENTS 311
Section 32 10 00 – Paving 311
Section 32 33 00 – Site Furnishings 311
Section 32 80 00 – Irrigation 312
Section 32 90 00 – Planting 314
DIVISION 33 – UTILITIES 315
Section 33 10 00 – Water Utilities 315
Section 33 30 00 – Sanitary Sewer 315
Section 33 40 00 – Stormwater Utilities 315
Section 33 50 00 – Natural Gas Utilities 315
Section 33 60 00 – Hydronic and Steam Utilities 316
Section 33 70 00 – Electrical Utilities 316
Section 33 80 00 – Communications Utilities 318
APPENDIX I - UPDATE / REVISION LOG 319

APPENDIX II – SUBMITTAL REGISTER 321
APPENDIX III – PROJECT CLOSEOUT CHECKLIST 322
APPENDIX IV – LIST OF NONASSIGNABLE SPACES 326
APPENDIX V – CALTECH INSPECTION PROCESS 327
APPENDIX VI – PHOTOGRAPHIC DOCUMENTATION 331
APPENDIX VII - A NOTE ON EARTHQUAKE DESIGN OF CALTECH BUILDINGS 332
APPENDIX VIII – FM Global Review Process 335
APPENDIX IX – Office Renovation Guidelines for New Professorial Hires 337
APPENDIX X – PLUMBING PIPING REQUIREMENTS 339
Caltech Campus Utilities (Plumbing and Mechanical) Table 339
Mechanical Piping Table 339
Plumbing Fixtures Table 339
Plumbing Piping Table 339
Mechanical and Plumbing Valve Table 339
APPENDIX XI – GENERAL MECHANICAL REQUIREMENTS 344
APPENDIX XII – MECHANICAL AND HVAC HYDRONIC PIPING REQUIREMENTS 346
Caltech Campus Utilities (Plumbing and Mechanical) Table 346
2026 Campus Centrally Delivered Utilities Specifications Table V5.5 346
Mechanical Piping Table 346
Plumbing Piping Table 346
Mechanical and Plumbing Valve Table 346
APPENDIX XIII – DUCT INSULATION, JACKETING, AND PRESSURE TESTING REQUIREMENTS TABLE 347
Duct Insulation, Jacketing, and Pressure Testing Table 347
APPENDIX XIV – CAMPUS UTILITY SHUTDOWN MATRIX 348
APPENDIX XV – COMPUTER AIDED DESIGN (CAD) and BUILDING INFORMATION MODELING (BIM) DELIVERABLE STANDARD 350
APPENDIX XVI – UTILITY SHUTDOWN REQUEST FORM 354
APPENDIX XVII – BUILDING CONTROLS GUIDE TEMPLATE 356
APPENDIX XVIII – General Contractor Safety Guide 360
APPENDIX XIX – CALTECH LANDSCAPE DESIGN PRINCIPLES AND MASTER PLANT LIST 361
APPENDIX XX – STANDARD DETAILS 362
APPENDIX XXI – BSL Laboratory Design Guide and Features 388
APPENDIX XXII – OLAR REQUIREMENTS 393
APPENDIX XXIII – FUME HOOD AND RELATED EXHAUST SYSTEMS MEMORANDUM OF UNDERSTANDING (MOU) 409
APPENDIX XXIV – CONTROL SPECIFICATIONS 414

APPENDIX XXV – ALARMS and POINT NAMING STANDARDS 415
APPENDIX XXVI – EXTERIOR SIGNAGE GUIDELINES 416
APPENDIX XXVII – DAS ERRCS Requirements 417
APPENDIX XXVIII – Fume Hood Selection Features 419
APPENDIX XXIX – Office & Lab Demo Protocol for Materials Recycling 422

DEFINITIONS

A/E: Architect / Engineer of Record for the Project.

Caltech: California Institute of Technology.

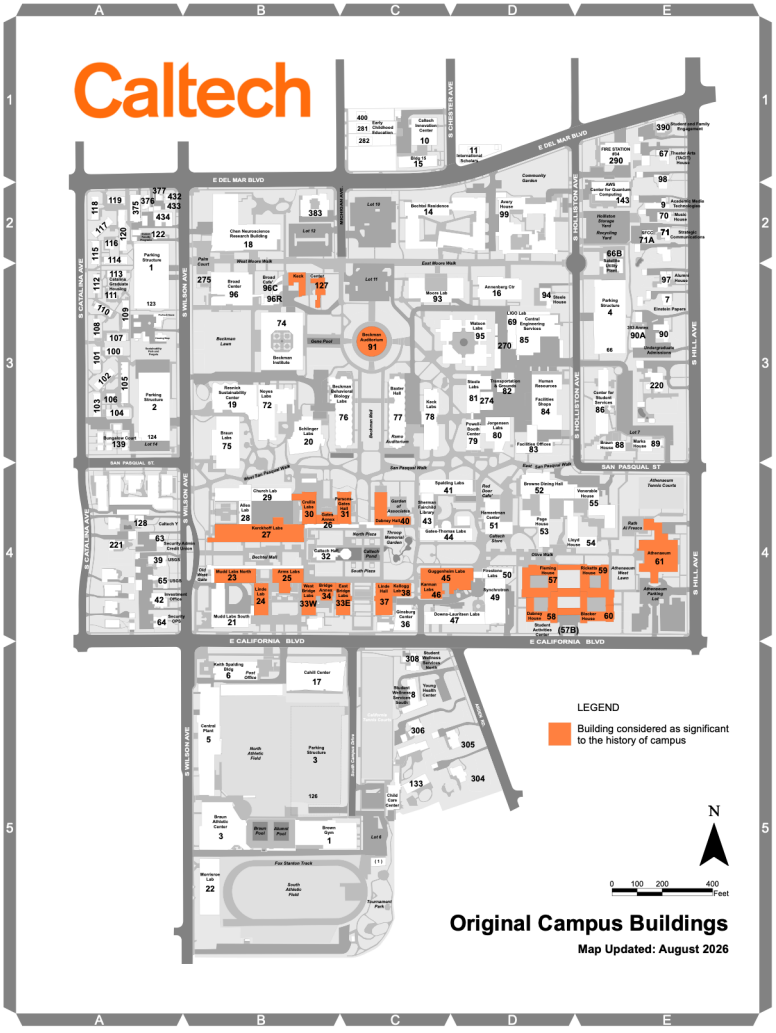
Code: All applicable building codes, fire codes, municipal codes, accessibility requirements, OSHA regulations, FM Global requirements (where applicable), and other applicable federal, state, and local laws, regulations, standards, and authority having jurisdiction (AHJ) requirements in effect as of the planning or permit date of the Project, whichever is later.

Fac Ops or **FOS**: Facilities Operations & Services department.

PD&C: Caltech Facilities Planning, Design and Construction department.

PEA: Caltech Facilities Planning, Design and Construction, Planning Engineering and Architecture department.

PM: Project Manager.



GENERAL REQUIREMENTS

1. **Purpose**

   a. The purpose of this document is to identify standards and materials that are required by Caltech as well as typical design and construction approaches applied at the Caltech campus. These standards shall be considered at the start of all projects and incorporated as applicable based on each project's scope of work. All deviations from these standards shall be submitted to the Caltech project manager in writing with a justification for the deviation. Justifications should address the benefits to Caltech and the total cost of ownership. Caltech shall respond in writing with a disposition to the request for the deviation. The Basis of Design (BOD) document, required on all projects as a deliverable during the design process, shall address adherence to the guidelines in specific detail.

   This document does not contain all requirements specific to any given project. Only those items where Caltech has a common preference or specific direction were included in this document. For example, Caltech has specific standards for laboratory casework because these are common facility requirements with specific performance requirements and manufacturers.

2. **Owner-Provided Information**

   a. The design team or the design-build team shall be provided with the design guidelines and owner's project requirements (OPR) at the start of each project. Other applicable information will also be provided as available such as reference drawings upon request. The design professional shall use the design guidelines in concert with the OPR developed specific to each project to prepare and execute all design services. In cases where the design guidelines are silent, the design team or design-build team shall provide recommendations. These recommendations shall be captured in the BOD. Recommendations shall be reviewed by Caltech and subject to comment and approval.

   b. Geotechnical Reports and Conditions: Caltech may retain a geotechnical engineer for performing certain inspection, testing, and observation functions required for a project. In this case, the geotechnical engineer will communicate only with Caltech, who will, in turn, relay any appropriate information to the design team, contractor, or design builder, with a copy to the design team, within the provisions of the contract documents.

   c. Project Survey:

      1) All project specific surveys shall provide benchmarks and monuments that will be compatible and coordinated with the most up to date campuswide survey.

      2) Consult Caltech project manager to request a copy of the most up to date campuswide survey in order to incorporate the project survey. Once incorporated, provide Caltech with the revised survey maintaining layer standards and format as originally provided by Caltech, highlighting all changes made and noting the date and other applicable information to track when and why this information was gathered.

3. **Commissioning**

   a. Caltech commissioning (Cx) guidelines shall be applied to all projects. The Caltech commissioning team oversees the Cx process, in coordination with the Caltech project manager, to ensure adherence to the commissioning guidelines. The commissioning team is comprised of stakeholders among Facilities departments, and, commonly, a third-party commissioning agent. This team shall select the applicable Cx tier at the start of the project. The Cx tier defines the required Cx scope for each project. The process is described in detail in the Caltech commissioning guidelines under separate cover.

4. **Submittal Register**

   a. Appendix II provides guidance on the submittals required by Caltech in the form of a template "Caltech Facilities Submittal Register." The submittal register template provided in Appendix II is not intended to be a complete list of required submittals. The design team or design-build team shall create and provide for Caltech's review and approval a project-specific submittal register for each project prior to the start of construction. This approved submittal register

shall be coordinated with the construction documents and specifications, and the design team or design-build team shall use it to track the submission of all submittals for each project.

5. Project Kickoff Meeting

a. At the start of each project, the Caltech project manager will schedule a project kickoff meeting with the design team or design-build team and project stakeholders, such as Caltech Facilities Operations and Services. The design team or design-build team shall address any questions regarding the design guidelines during this meeting. It is critical to have a clear understanding of the requirements of the project at the start of the project.

6. Deviations from the Design Guidelines

a. The design guidelines are frequently edited based on new products, improved total cost of ownership, and Caltech experience, making this a "living" document. In the event the design professional believes that a design guideline is not recommended for a specific Caltech project, the project team shall discuss specific recommendations with the Caltech project manager. When the project team believes they cannot, or should not, comply with specific design guidelines, they shall submit those items in writing to the Caltech project manager.

7. Campus Information

a. Location: Caltech's main campus is located in south central Pasadena, south and east of the Lake Avenue and Colorado Boulevard commercial corridors. The campus is bordered on the north and west by two- to three-story apartments and condominiums along the Mentor Avenue–Catalina Avenue and Cordova Street–Del Mar Boulevard corridors.

b. Neighborhood: To the south and east of campus are established and well-maintained single-family neighborhoods that date from the early 1900s. The predominant one- and two-story housing stock in these areas range from more modest dwellings on smaller lots near Del Mar Boulevard to much larger homes on estate-sized lots in southern areas of the city.

c. Main Campus: Presently, the Caltech main campus located at 1200 East California Boulevard in Pasadena, California, encompasses approximately 127 acres. Approximate boundaries for the campus are:

1) Catalina Avenue on the west
2) Del Mar Boulevard on the north
3) Hill Avenue on the east
4) California Boulevard from Hill Avenue to Arden Road on the southeast, and
5) Arden Road, Tournament Park, and Wilson Avenue on the south

d. The Caltech Original Campus is an area of Caltech's main campus bounded by California Boulevard on the south, San Pasqual on the north, Hill Avenue on the east, and Wilson Avenue on the West.

e. Satellite Facilities: Caltech owns or operates satellite facilities elsewhere in Pasadena and Southern California, which currently include:

1) Jet Propulsion Laboratory – Pasadena, CA
2) Palomar Observatory – San Diego County, CA
3) Owens Valley Radio Observatory – Inyo County, CA
4) William G. Kerckhoff Marine Biology Laboratory – Corona del Mar, CA, and
5) Other properties outside the campus boundary but within the city of Pasadena

8. Applicable Codes, Regulations, and Ordinances

a. Codes and Regulations: All design efforts shall conform to the applicable codes and regulations per the City of Pasadena including, but not limited to the following:

1) California Code of Regulation, Title 24, Parts 1–12
2) California Building Code Chapters 1–35 and Appendices C, H, I, and J
3) California Residential Building Code
4) California Electrical Code
5) California Mechanical Code

6) California Plumbing Code
7) California Energy Code
8) California Historical Building Code
9) California Fire Code
10) California Existing Building Code
11) California Green Building Standards Code (CALGreen)
12) Americans with Disabilities Act (ADA)

b. Ordinances: The design team and design-build team shall design any given project to conform to all applicable County of Los Angeles and City of Pasadena ordinances including, but not limited to, the following:

1) Pasadena Municipal Code, Title 12 – Streets and Sidewalks
2) Pasadena Municipal Code, Title 13 – Utilities and Sewers
3) Pasadena Municipal Code, Title 14 – Buildings and Construction
4) Pasadena Municipal Code, Title 17 – Zoning

9. FM Global Review Process

a. Projects are subject to review and approval by Caltech's casualty insurance carrier and shall comply with FM Global requirements. See Appendix VIII for which processes are applicable to this review.

10. Caltech Finance, Facilities, and Infrastructure Committee Project Approvals

a. Approvals and reviews needed by the Finance, Facilities, and Infrastructure (FFI) committee of the Board of Trustees shall be coordinated with the Executive Director of Planning, Design & Construction. Approvals typically include capital construction projects with total project costs greater than $10 million, construction of new buildings, renovation of existing facilities, and projects intended to change exterior campus elements, including building exteriors and open space.

b. Presentations to the FFI committee typically require a description of the project and all associated project costs. The description of the project includes purpose, scope, and schedule. The project description will address how the project will align with the Institute's sustainability objectives. The proposal shall also include a project cost estimate, maintenance and operating cost impacts, and a funding plan.

c. Project status will be reported to the committee each time the committee meets. The status update will include project progress as well as proposed scope, schedule, and budget changes. If, during the course of the project, execution costs are anticipated to exceed a previously approved budget by 10 percent of project cost or $500,000, whichever is greater, the budget change will require separate approval by the Finance, Facilities, and Infrastructure committee and Board of Trustees.

d. Refer to **Doc E Capital Construction Guidelines 240927** for current approval procedures and requirements.

11. Artwork

Caltech has an Institute Art Committee. The committee membership rotates on a regular basis. The Institute Art Committee reports to the President. The Provost shall be involved if the artwork requires a significant use of space or impacts the use of academic space. Advancement and Alumni Relations shall be involved if the project involves a donor gift, and Strategic Implementation should be involved if there are communications or strategic implications.

12. Sustainability

a. Caltech is committed to ensuring the existing and future facilities on campus meet and maintain a high level of energy, water, and resource efficiency. As a responsible steward of resources including the environment, equipment, facilities, money, and people, Caltech seeks to be conscious of the Institute's impact. Caltech takes a long-term view regarding the ownership, operation, and maintenance of its buildings and infrastructure and uses life-cycle analysis in planning decisions.

b. These aims shall be achieved using the sustainability principles outlined within each section of these design guidelines. While the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) guidelines help to inform the design and construction process, Caltech firmly believes that LEED certification in and of itself is not the goal. The goal is building the most durable, efficient, and sustainable building practicable while considering capital costs and long-term maintainability and operating costs.

c. All new buildings, projects, and major renovations will be designed to achieve at least LEED Gold certification with the goal of achieving exemplary performance wherever feasible. Project design should take into consideration the full life-cycle cost, including environmental impacts, of operating and maintaining this type of high-performance building and how the building will operate as efficiently as possible within the existing campus infrastructure. To incorporate environmental impacts into Caltech's design review, all new buildings and significant renovation projects should incorporate a proxy price of carbon in the decision-making process. This carbon price will be determined by the current California carbon allowance price as the base and the social cost of carbon used by Facilities Planning, Design & Construction as the ceiling.

d. All other renovation projects will be designed to minimize environmental impact by maximizing energy and water efficiency and reducing project waste to the greatest extent possible. These projects should also be designed in concert with other renovation or retro-commissioning projects planned or under way in the subject building in an effort to maximize building system efficiency and minimize interference with ongoing building operation. LEED for Existing Buildings Operations and Maintenance (EBOM) shall be considered and reviewed with Caltech project manager and sustainability manager for existing buildings seeking LEED certification for the first time and projects previously certified under LEED for New Construction.

e. Caltech prioritizes planning and implementation of "scale jumping" sustainable design projects at the campus level for energy, water, carbon reduction, and transportation. Leveraging campus sustainability attributes, aligning building designs to readily access/contribute to campus-scale efforts, and recognizing the economics of campus-scale solutions should be reviewed as part of building-level sustainable design for each project.

f. Resiliency planning is increasingly important to Caltech in response to long-term climate trends as well as episodic natural events. The design team (architect and engineer) should consider and review resilience risks, priorities, and assessment strategies with Caltech project manager for each new project. Project design teams shall consider climate change in the design of the building. This will include consideration of:

1) Gradual climate change – modeled change in temperature and precipitation; and

2) Disaster scale climate/weather events – modeled projections of frequency and intensity of events.

At a minimum the following should be addressed:

3) Project design teams are strongly encouraged to include LEED resilient design credits in the scope of the project's LEED credits.

4) Project design teams are encouraged to consider the value of energy- and water-saving measures to the project's resilience.

5) Project design teams are encouraged to consider designing a building such that its critical functions are resilient, meaning that non-critical program elements could go offline during a climate event for the benefit of preserving utility service to critical functions.

6) Projects must employ stochastic weather modeling in project energy modeling and in consideration of design conditions for building systems selection and sizing.

(a) Every project that includes an energy model shall employ a model that predicts future temperatures. Each entity engaged as an energy modeler for Caltech projects must present the university with three recommended vendors from which to source the future weather data. The energy modeler undertaking the modeling shall provide an assessment of the benefits and shortcomings of each vendor's methodology.

(b) For projects that leverage future weather data for modeling, the design team should also require the data vendor to develop ASHRAE design conditions tables similar to historical data from the ASHRAE Fundamentals Handbook, but that reflect the future data.

(c) For projects that leverage future weather data for modeling, the design team should also require the data vendor to develop future precipitation data that can support sizing of stormwater systems.

g. All projects should aim to reduce embodied carbon by choosing low emissions building materials, furnishings, finishes, and equipment. Use of product LCAs to determine third-party verified scope 3 emissions is necessary to meet LEED V5 certification.

h. Non-virgin and recycled materials should be prioritized for all practical applications, including but not limited to doors, trimming, and walls. Low volatile organic compound (VOC) content shall be used for painting, coatings, finishes, and adhesives, as required by applicable regulations. Material selections should prioritize reduced environmental impact. Evaluation of material options using life cycle assessment (LCA) methodologies and environmental product declarations (EPDs) should be considered where available to support informed decision-making. Documentation of embodied carbon and other environmental impacts associated with material selections should be considered on new building projects.

i. Solar PV Structure: Caltech has implemented rooftop solar PV generation to reduce greenhouse gas emissions and provide reliable onsite energy. The goal is to continue moving the campus towards renewable generation in the future. Caltech suggests the following during the building design stage to allow for higher penetrations of solar PV at Caltech:

1) Design building structure and rooftop to allow for solar PV including supporting structures.

2) Consider locating solar PV above mechanical equipment such as air handler units, etc., with proper clearance.

3) Design a flexible clear corner spot(s) (i.e., 15 feet x 15 feet) to allow mechanical equipment to be moved in and out of the roof if needed and/or the single pieces of mechanical equipment are above 500lbs.

4) Provide the means (anchors with metal plates) to mount steel columns for solar PV structures.

5) Install 4–inch conduits from roof into main electrical rooms for solar PV electrical power use.

6) Install 1½–inch conduits from roof into main electrical rooms for solar PV communication.

13. Design Criteria per Room or Function

A. Provide sound control around offices, conference rooms, toilet rooms, mechanical rooms, and other sensitive areas for new building and renovation projects. Required sound transmission class (STC), noise criteria (NC), and other ratings to be coordinated with Caltech PD&C by room or area function. The requirements of these Design Guidelines are minimum requirements. Where conflicts exist between these Design Guidelines and applicable codes or referenced standards, the more stringent requirement shall govern. Deviation shall be discussed and approved by Caltech Director of PEA.

a. STC requirement for typical rooms:

The minimum Sound Transmission Class (STC) ratings below establish the required airborne sound isolation between adjacent spaces. STC ratings are minimum laboratory-tested ratings for the complete partition assembly. Equivalent tested assemblies from any manufacturer meeting or exceeding the specified STC rating are acceptable. Higher STC ratings shall be provided where required by programmatic, privacy, or research-specific needs.

Adjacent Spaces	Minimum STC Rating
Office to corridor	**STC 35**
Laboratory to corridor	**STC 35**
Classroom to corridor	**STC 40**
Conference room to office	**STC 44**
Office to office	**STC 44**
Conference room to conference room	**STC 50**
Classroom to classroom	**STC 50**
Vivarium space to adjacent mechanical or equipment room	**STC 60** *(STC 50 may be acceptable with approval from the Caltech Director of PEA and Director of OLAR, and must be supported by equipment selection and acoustical analysis.)*

b. Typical room noise criterion (NC) per function:

Space Function	Design Target
Computer and server rooms	**NC 50–65**
Laboratory equipment corridors	**NC 45–60**
Corridors and public circulation areas	**NC 45–55**
Open-plan offices	**NC 35 - 40**
Private offices	**NC 30–35**
Seminar rooms	**NC 30–35**
Conference rooms	**NC 30–35**
Classrooms	**NC 30**
Teaching laboratories	**NC 30–45**
Research laboratories	**NC 35–45**, up to **NC 50** where lab equipment noise or other requirements justify higher background noise
Precision research laboratories (e.g., LIGO, AMO, quantum, optics, advanced microscopy)	**NC 25–35**, or lower where required by specific instrumentation

B. Standard Laboratories: Provide the following:

1) Vinyl Flooring: Solid pattern type premium floor tile (12 inch by 12 inch) equivalent to
   i. Armstrong
   ii. Forbo
   iii. Tarkett
2) Rubber Flooring: tile flooring equivalent to
   i. Forbo
   ii. Nora by Interface
   iii. Tarkett
3) Rubber cove base at walls, preferably provided in 120' rolls.
4) Stainless steel receptacle and switch plates, with color-coded devices.
5) Caltech's current standard communications outlets. Lab areas that require a landline phone for communication purposes, the phone shall be wall-mounted to limit the potential of lab incidents and contamination. Phones shall be mounted in a way that cords are not lying on the benchtop and shall be located near the exit of the lab in a safe location. Phone to be installed in a CBC and ADA accessible location, at a CBC and ADA accessible height.
6) Emergency eyewash showers. (See Appendix X, Plumbing Piping Requirements, for model information)
   i. Emergency eyewash and shower equipment shall be located on the same level as the hazard, have un-obstructed access (a door is interpreted to be an obstruction), and require not more than 10 seconds (55 feet) to reach. Location to be approved by Caltech EH&S.
7) Marker boards and accessibly mounted telephones, at entrances to laboratory areas.
8) Tackable cork surface bulletin boards, such as Forbo, with aluminum perimeter frame, at desk areas.
9) Tempered glass or polycarbonate splash guard, ½–inch thick, in aluminum channel, between wet benches and desk areas.
10) Provide lab coat hooks / racks in every lab work area. Specific locations of coat hooks / racks shall be coordinated with Caltech project manager.
11) Provide polycarbonate mats under manifolds. Coordinate with Caltech project manager.
12) Air, gas, and vacuum services in labs shall be set left to right.
13) Avoid occupancy sensor lighting control in labs.
14) When laboratory casework is set against a wall, data ports shall be located on the walls.
15) Vacuum breakers on domestic water will be used on a case-by-case basis. Coordinate with Caltech project manager.
16) Ductless Fume Hoods are not recommended at Caltech. Consultation with EH&S is required prior to any ductless fume hood planning and requires assessment and approval from EH&S. Coordinate with project manager to get required approvals.
17) Provide roll paper towel dispenser at all lab sinks. Where not possible to mount a roll paper towel dispenser, provide countertop folded paper towel dispenser. Product selection to be approved by Caltech project manager and the Director of Buildings & Grounds. Dispenser equivalent to:
   - Roll paper towel dispenser option 1: Scott® Pro Automatic Hard Roll Towel Dispenser PRODUCT CODE #35614 (Grey core)
   - Roll paper towel dispenser option 2: Scott® Control Slimroll Electronic Towel Dispensers PRODUCT CODE #47260
   - Folded paper towel dispenser: Tork Xpress Countertop Multifold Hand Towel Dispenser, in black #302028 or brushed stainless steel #302030.
   - Folded paper towels: project to provide first and second refill of Tork Premium Multifold Hand Towel #420580
18) Lab bench base units to be 22" deep. Provide matching closures at exposed ends and knee space backs. Include a duplex outlet at each knee space, typical.

19) Bench height to be 36” nominal finished. Provide 34” bench height in designated accessible areas of the lab. Coordinate with PD&C architect on accessibility provisions for each lab. Desk height to be 30” nominal finished.

20) All laboratory entrance doors to have self-closers with soft close mechanism.

21) Computers, task chairs, biosafety cabinets to be owner furnished–owner installed (OFOI).

22) Fume hoods, flammable cabinets to be provided by contractor.

C. Clean Room/Biocontainment Laboratories:

For the design features and requirements of biocontainment laboratories (BSL1 to 3), refer to Appendix XXI, BSL Laboratory Design Guide and Features.

1) **Flooring**: Implement flooring requirements depending on the level of cleanroom. Use one of the following products:
   - **i.** Sheet vinyl, welded seams, with 6-inch-high coved base. This will give the floor a clean monolithic surface. Manufacturer's material certifications should be provided. Coved floors keep air from vortexing in the corners, keeping floor cleaner.
   - **ii.** Epoxy coating: cove floor to wall intersection.
   - **iii.** Class 10,000 (ISO 7) and Class 100,000 (ISO 8): Either sheet vinyl or VCT are acceptable.
2) **Walls**
   - **i.** Traditional walls: Constructed from metal studs. Studs shall extend from floor to underside of deck above. Provide minimum 5/8-inch-thick moisture-resistant gypsum board screwed to studs, mud and tape. Cove the intersection of the ceiling and the wall planes and the vertical wall-to-wall corners with 2-inch radius pre-molded cove flush to wall. Provide an epoxy wall sealer and epoxy smooth coat final finish. Note: Provide fiberglass reinforced panel (FRP) veneer (over partition) or modular wall system in lieu of this option if walls are subject to impact.
   - **ii.** Modular Wall System: factory-fabricated panels configured in modular sizes in various styles and finishes, including tempered glass panels, plastic panels with steel frames, powder-coated steel with foam insulation core, and stainless steel with foam insulation core.
   - **iii.** If the project is in an older structure, the wall is to be constructed to match the existing condition, which may be plaster. A mock-up of the proposed match will be required.
3) **Ceilings**: Shall be clean and free from any dust edges. Overhead piping and conduit shall be concealed.
   - **i.** Gypsum Board Ceiling: Use with gypsum board wall system. Suspend below structural framing just enough to recess the lighting fixtures, mechanical ductwork, plumbing, and electrical runs. Use moisture resistant gypsum board with a plaster finish and epoxy paint system. Also, use the 2-inch minimum, pre-molded wall / ceiling cove and corners to ensure that the room interior is a contiguous surface, known in the industry as "bathtub construction."
   - **ii.** Modular Panel System: If modular walls are used, consider a modular ceiling, which will coordinate with the wall construction.
4) **Doors**
   - **i.** Aluminum Profile Clean Room Doors: Custom aluminum extrusions with double perimeter seals and optional door bottom drop seal featuring a flush jamb and leaf assembly. Available with upper and optional lower flush glazing and finished with an epoxy powder coat for maximum durability and chemical resistance. Preferred manufacturer: Plascore Pharma (www.plascore.com).
5) **Lighting**: Clean room lights shall be sealed and can be surface mounted. Fixtures are required to be recessed when in clean rooms Class 10,000 (ISO 7) or cleaner, conforming to the latest ISO 14000 series cleanliness standards.
6) **Mechanical**: Keep clean room laboratories on positive pressure and high efficiency particulate air (HEPA) filtered at all air supply grilles, which shall be top down even air distribution system. The returns shall be along the perimeter of the room, just above the coved base at the perimeter walls (known as laminar flow); required for laboratories required to be Class 10,000 (ISO 7) or cleaner. This classification requires an anteroom before entering the lab space. This is crucial to keeping the particulate count to the specified level.
   - **i.** Biocontainment laboratories are on negative pressure with no air recirculation in other areas. Negatively pressured anteroom might be required upon risk assessment – Consult with Caltech biosafety officer.

D. Laser Laboratory: Environmental Health and Safety (EH&S) shall be consulted in the design stage of a laser laboratory. In general, the following design elements are required for Class 3b and Class 4 lasers:

1) Laser Warning Light:

i. Type: An illuminated light with the appropriate Class 3B or Class 4 laser warning sign. It shall display the laser class, laser hazard symbol and appropriate hazard in accordance with ANSI Z136.1 – 2022 standard. It is recommended that the warning sign be of an inset flush type.

ii. Location: Shall be next to the door, near eye height, not over 2 meters (6 feet) above the floor (ANSI Z136.8-2021).

iii. Activation Mechanism: Shall be activated when the laser power is activated.

2) Laser Curtain Barrier

i. Laser beam blocking curtain, area barriers or windows must be made of a material suitable to block or attenuate the primary or scatter beams of laser or laser system. The protective device must be appropriate for laser type, temporal mode of operation, and wavelength(s). They must be rated in Watts per square centimeter (W/cm2) for a minimum of 100 seconds, in accordance with ANSI Z136.1 – 2022, Z136.7 – 2025 or EN 12254 – 2010. Typically, the EH&S Office will provide the evaluation for the laser barrier rating. Laser curtain barriers shall not be of flammable material, and they shall meet NFPA-701:2023 TM2 standards. They must also display the barrier threshold level as identified by the manufacturer and the CA fire marshal certificate in a visible location.

b. Janitor's Closets: A janitor's closet is required on each floor.

1) One 8-foot by 12-foot closet shall be located in the basement or ground floor (ideally near a service elevator). This closet shall store custodial carts and equipment utilized in the area and paper goods for the building.

2) The remaining closets shall be 6-feet by 8-feet minimum and shall be located on each floor. These spaces shall be usable space for daily janitorial operations.

3) All closets shall include a service sink with a splashguard, hot and cold water, as well as a minimum of one electrical outlet.

a. Refer to Section 22 40 00 - Plumbing Fixtures for exact specification.

4) Sink faucet: Refer to Section 22 40 00 - Plumbing Fixtures for exact specification.

5) Shelving: Each closet shall have overhead storage with a minimum of three shelves, a utility shelf with mop/broom holders, and rag hooks and two wall hooks for ladder safety. Closets shall have seismic wire provided along all shelving.

c. Restrooms

1) **Tile grout:** White and black grout are not permitted for floor or wall tile. Provide medium-tone grout colors to minimize visible staining and simplify maintenance.
2) **Floor slope:** Slope the entire restroom floor toward floor drains to prevent standing water and facilitate cleaning.
3) **Floor drains:** Provide floor drains in all public and staff restrooms unless otherwise approved by Caltech.
4) **Base:** Provide integral coved tile base or other durable, cleanable base at all tiled walls.
5) **Sealants:** Use mildew-resistant, color-matched sealants at all changes in plane and around plumbing fixtures.
6) **Accessories:** Coordinate locations of accessories with wall backing and accessibility requirements prior to construction.
7) **Partitions:** Toilet partitions shall be solid phenolic or HDPE. Powder-coated steel is not permitted unless approved by Caltech.
8) **Countertops:** Solid-surface countertops are preferred. Plastic laminate countertops are not permitted.
9) **Finishes:** Select finishes and fixtures for ease of maintenance, durability, and resistance to moisture, staining, vandalism, and cleaning chemicals. Large tiles are encouraged to minimize grout lines.
10) **Ceilings:** Provide washable, scrubbable, moisture-resistant acoustical ceiling panels with a cleanable finish. Exposed suspension systems shall have a corrosion-resistant finish. **Hard-lid ceilings should be avoided unless required for architectural design, security, or other project-specific conditions approved by Caltech.** Ceiling panels shall be washable, scrubbable, moisture-resistant, and have a minimum sag resistance suitable for high-humidity environments (e.g., ASTM C367 High Humidity performance).

d. Ceiling Clearances. Various requirements for all projects and room types:

1) If the building is sprinklered, a minimum of 18" clearance is required between the ceiling and any object stored on shelves, bookcases, etc.

2) If the building is not sprinklered, a minimum of 24" clearance is required between the ceiling and any object stored on shelves, bookcases, etc.

3) Provide adequate clearance above ceiling tiles for general maintenance and access.

4) For all projects: Demo all existing unused systems, utilities and associated supports, and patch and repair surfaces. In exposed ceiling areas: paint all visible surfaces including utilities and associated supports. Deviation to be approved by PM.

e. Knox boxes: to be mounted on bollards only.

f. Markerboards: Acceptable markerboard types: back-painted glass or porcelain enamel steel with low gloss finish and magnetic capacity. Discuss any deviations, including wall talker specifications, with Caltech PM. Acrylic and melamine markerboards are not acceptable.

14. For asset and BMS naming standards, go to https://facilitiesoperations.caltech.edu/assetmanagement/namingstandards. Use the latest version on website.

15. For environmental health and safety standards, go to http://safety.caltech.edu/manuals or email safety@caltech.edu**.** Information regarding hazardous materials and other relevant information can be found there.

16. For wired, wireless, and remote access guidelines, go to http://imss.caltech.edu/services/wired-wireless-remote-access/construction-requirements information regarding contractor qualification requirements and information management systems guidelines.

17. Drone Use Application:

Any construction related use of drones shall require a UAS application to be submitted and approved by Caltech. Application is building specific; no flyover is allowed to any adjacent building or site without being approved.

Complete an Application for Use of Unmanned Aircraft Systems (Drones) & Other Airborne Objects form and send to Caltech PM for review and process.

18. DAS ERRCS radio communication:

New buildings to comply with DAS ERRCS code requirements and systems applicable to the project. See Appendix XXVIII for a brief description of requirements that Caltech is providing for reference only. The design team is responsible for obtaining the latest applicable standards and requirements and complying with regulations in full.

PROJECT DELIVERY

1. **General:**
   - **a.** Caltech shall determine the preferred project delivery method on a project-by-project basis. The execution of the delivery method selected shall be done in a transparent and efficient manner by all parties.
2. **Design:**
   - **a.** Design and construction documents shall be organized according to the Construction Specifications Institute (CSI) Master Format, latest edition. Deliverables shall entail complete construction documents to include drawings, specifications, basis of design (use Caltech template), submittal register (see Caltech submittal register as a guide, available on Caltech's Design & Commissioning Guidelines website), response to comments (option to use Caltech template), calculations, cost estimates, and finish boards. Submit finish/material sample to Caltech Facilities Planning, Engineering & Architecture prior to presenting to the user group. Provide a labeled finish/material board and schedule. Physical boards are preferred. Digital board may be acceptable for small projects with Caltech PM approval. Update finish/material boards and schedules throughout the design and construction phase to reflect approved selections and project changes.
   - **b.** Specifications shall be in Arial font 10 PT. Coordinate with Caltech on the format of the specifications. Cost estimates shall be organized by CSI specification format. Caltech logo shall be placed on all construction documents. The authorized logo can be downloaded from Caltech's identity toolkit (Caltech credentials required).
   - **c.** Refer to Appendix XV for deliverable requirement on CAD, BIM, and pdf format.
   - **d.** For major projects, model(s) may be required as well as mock-ups.
   - **e.** For major projects, BIM will be required. The design team and the design-build team shall submit a BIM execution plan for review and approval by Caltech.
   - **f.** Use of phrase "or equal" in project specifications shall be avoided. The design professional shall endeavor to find three products of similar quality to specify, unless otherwise noted in this document. The design professional shall notify Caltech if three equivalent manufacturers and products are not available, or if any standard-specified items are not appropriate for the project.
   - **g.** Note that there are select materials or equipment that are required regarding manufacturer and model number. For those items, other manufactures do not need to be listed.
   - **h.** Architectural Visualizations: Caltech strives to become an example of how a diverse and inclusive community, committed to equity and accessibility, permits individuals to thrive in fulfilling the Institute's mission of forefront research and education. Architectural visualizations in all formats, including computer-generated imagery, are to represent Caltech's diverse and inclusive community and Caltech's commitment to promoting and strengthening inclusion, diversity, equity, and accessibility.
   - **i.** It is the design-build team's responsibility to plan for equipment placement and verify equipment sizes, clearances, and utility needs. All fixed utilities and lab accessory placement (PPE, coat hooks, wall phone, switches, power/data receptacles, lab gas valves, thermostats, etc.) shall be coordinated and documented during project design phase.
   - **j.** Campus single line drawings shall be updated after each project is completed. The as-builts provided by the project team shall be sent to the Caltech electrical engineer by the Caltech project manager. The Caltech electrical engineer shall mark up the campus single lines and make the changes themselves digitally in Meridian or shall get assistance from Caltech support staff to enter this information digitally in Meridian. The same applies to all other building systems and utilities.
   - **k.** Permit application drawing sets submitted to the authority having jurisdiction (AHJ) shall identify the Caltech project location and responsible Institute contact. The permit application drawings shall include the Caltech building number, building name, floor(s) affected, and room number(s) affected by the project. The drawings shall also identify the Caltech project manager, including contact email, and include the Caltech permit coordination contact, **permitcenter@caltech.edu**. This information shall be provided on the cover sheet or within the project title block to ensure proper identification of the project within the Caltech campus and to provide the appropriate point of contact during the permit review process.

I. Project Delivery Platform: Caltech will utilize Autodesk Construction Cloud (ACC) /Autodesk Forma as the project management platform. All project consultants and contractors should use ACC for project information management and coordination throughout planning, design, and construction. All project participants shall comply with Caltech ACC requirements.

DIVISION 01 – GENERAL REQUIREMENTS

Section 01 43 00 — Quality Assurance

1. **Testing and Inspection**
   a. **Testing Agency:** Caltech shall retain and pay the expense of a testing agency to perform and report on work specified in the contract documents. The testing agency may be a commercial testing organization, the testing laboratory of a trade association, the certified laboratory of a supplier, or other organization. The testing agency shall have been in business for a minimum of five years.
   b. **Special Inspection:** Caltech will retain special inspection services as required by the California Building Code, and as specified in other sections. The special inspector shall be a registered deputy building inspector within the City of Pasadena. Special inspections will not be required when the work is done on the premises of a fabricator approved by the regulatory agency.
   c. **Qualifications of Testing Agency**:
      1) Meet recommended requirements for independent laboratory qualifications, published by the American Council of Independent Laboratories.
      2) Meet the basic requirements of ASTM E329, Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection.
      3) Authorized to operate in the state of California.
   d. **Test Reports**: Testing agency shall distribute both hard and soft copies of all reports as follows:
      1) Design Professional: One hard and one soft copy.
      2) Caltech Planning, Design & Construction: One hard and one soft copy.
      3) City of Pasadena: One hard and one soft copy.
      4) Number of copies for contractor and supplier being tested will be determined upon commencement of contract.
   e. **Multiple Tests and Inspections**: Certain portions of the work will be tested or inspected at various stages, sometimes off site, between their inception and final positioning in the completed work. Nothing in any prior acceptance or satisfactory test result shall govern if at any subsequent time the work, or portion thereof, is found not to conform to contract documents.
   f. **Additional Testing and Inspection:**
      1) If initial tests or inspections made by the testing agency reveal that materials or project performance do not comply with the contract documents and specifications at the discretion of the design professional and/or Caltech inspector, additional tests and inspections shall be made as directed and expensed solely by the contractor.
      2) If additional tests and inspections establish that materials comply with contract documents, all costs for such tests and inspections may be reimbursed by Caltech.
      3) If additional tests and inspections establish that materials do not comply with contract documents, all costs of such tests and inspections shall be deducted from the total contract value.

Section 01 43 39 – Mock-ups

1. **General Mock-up Requirements:**
   - **a.** The intent of mock-ups is to ascertain elements designed to fit into space provided and provide contractor the opportunity to coordinate subcontractor work, and to show finish and workmanship expected for finished work that meets project specifications and Caltech standards.
   - **b.** Approved work can be included as part of final construction. Consult with Caltech project manager before conducting mock-ups for approval.
   - **c.** Mock-ups include, but are not limited to:
     - **1)** Major handrails
     - **2)** Firestopping
     - **3)** Laboratory casework and fume hoods
     - **4)** Specialty finishes and construction
     - **5)** Mechanical, electrical, and plumbing sequencing and layout
   - **d.** Maintain quality control over work of various sections of specification, manufacturers, products, services, workmanship, and site conditions, to produce mock-ups in accordance with contract documents and Caltech design guidelines.
   - **e.** Contractor to produce mock-up of specified quality using appropriately qualified personnel.
   - **f.** Provide finish to match approved samples.
   - **g.** Construct mock-ups as complete assemblies, including specified attachment and anchorage devices, flashings, seals, and finishes.
   - **h.** Remove unacceptable mock-ups.
   - **i.** Mock-ups shall be approved by design professional and/or Caltech project manager in writing, prior to commencement of the work.
2. **Laboratory Mock-up:**
   - **a.** Provide a full-scale mock-up of typical laboratory spaces for a two stage (rough-in and finish) review by Caltech. The laboratory mock-up shall include all materials including basic peninsula, basic wall units, fume hood, and utility lines. The actual utilities and equipment do not need to be functional or energized. Location of mock-up room will be determined by Caltech.
     - **1)** If specifically requested by Caltech, construct mock-up laboratory “out of sequence” and not located in place, and available for review before beginning the remaining rough-in stage and finish stage.
     - **2)** Order the materials and equipment for the mock-up room immediately after notice to proceed or as determined by the design professional and/or Caltech project manager.
     - **3)** Construct rough-in stage of the mock-up laboratory out of sequence and obtain approval by Caltech before beginning remaining rough-ins in other laboratory spaces.
     - **4)** Construct the “complete stage” of the mock-up laboratory space out of sequence and obtain approval from Caltech before beginning the finishes (complete stage) in laboratory environments.
     - **5)** Approval will not be given for any parts of the mock-up until all the work of the entire project phase (rough-in or complete) of the mock-up is in place.
     - **6)** In the event that problems with coordination of work of different trades becomes apparent during the construction and review of the mock-up and results in design changes, Caltech shall be responsible only for replacement of work in the actual mock-up construction that satisfies the original design and quality requirements as indicated in the contract documents. The contractor shall be responsible for replacing, without alteration of the contract sum or the contract time, any such work outside the extent of the mock-up that is provided before approval of the mock-up construction, and which must be replaced due to design changes resulting from the mock-up review.

7) Rough-in stage of laboratory spaces shall be complete with metal stud walls and the following:
- **i.** Rough plumbing
- **ii.** Rough electrical
- **iii.** Sprinkler piping installed with head locations indicated
- **iv.** Mechanical hydronic piping and air distribution (supply, return, and exhaust – as applicable).

8) The complete stage mock-up shall include all painting and installation of the following items:
- **i.** Flooring
- **ii.** Finish ceiling
- **iii.** Doors and hardware
- **iv.** Laboratory casework, countertops, drawer units, cabinets, shelving, sinks with all fixtures, lab gas/utility outlets, markerboards, tech desks, wire mold, and splash guards
- **v.** Window covering
- **vi.** Light switches, electrical outlets, thermostat thermometer
- **vii.** Partition closure and window on exterior wall
- **viii.** Ceiling light fixtures and under-cabinet task-light fixtures. Light fixtures shall light up.
- **ix.** Sprinkler heads, fire alarm horn/strobe, and smoke detector
- **x.** Ceiling air diffuser
- **xi.** Equipment, except Caltech-furnished equipment
- **xii.** Acoustic insulation
- **xiii.** Epoxy flooring, wall coating, and ceiling coating, as specified
- **xiv.** Door and hardware, including view windows and covers
- **xv.** Stainless steel countertops, sinks with faucets, gas/utility outlets
- **xvi.** Light switches, electrical outlets, temperature and humidity sensors and controls, telephone and data outlets, intercom speakers, and all weather-resistant covers
- **xvii.** Light fixtures, with lamps and power for operation
- **xviii.** Sprinkler heads and all fire or smoke detection or alarm devices
- **xix.** All access panels, diffusers, and grilles
- **xx.** Equipment, including Caltech-furnished equipment
- **xxi.** All architectural finishes
- **xxii.** Fume hoods

Section 01 43 39.1 – Interior Mock-ups

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
1. Interior lab classroom mock-up, constructed on-site, out of sequence, within building shell.
2. Engineering of mock-up elements as required to implement scope.
3. Design of mock-up, including shop drawings, showing configuration as specified and designated elements as shown on drawings.
4. Disposal of mock-up.
5. Testing payment as indicated.

B. This section does not represent or limit application of mock-ups specified in individual sections.

C. Refer to applicable sections in Division 02 through Division 33 for requirements for mock-ups specific to individual sections.

1.2 ADMINISTRATIVE REQUIREMENTS

A. **Pre-Fabrication / Pre-Installation Meetings**: Prior to starting fabrication or installation of mock-ups, schedule meeting at mutually acceptable time with owner, owner's consultants, architect, contractor, affected subcontractors and installers, affected manufacturer's representatives, and other parties affected by mock-ups to review materials, methods, and procedures required for mock-ups.

1.3 SUBMITTALS

A. **Submittal Processing**: To expedite ordering of components and materials required to construct mock-ups, provide submittals as required to obtain approvals of mock-upcomponents and materials.

B. **Product Data**: Prior to construction of mock-ups, provide material samples as specified in the respective specification sections that are included as part of the mock-up.

C. **Shop Drawings**: Prior to mock-up fabrication, submit shop drawings for mock-up that integrate shop drawings specified in applicable sections for each component and finish material required for mock-up.

1. Clearly identify components and materials to be integrated into mock-up.
2. Provide complete details of all materials, clearly showing sequence of installation, method of installation, and all components necessary to fully describe mock-up.
3. Indicate manufacturer and model number of individual components.
4. Provide axonometric drawings for conditions difficult to illustrate in twodimensions.
5. Prior to mock-up fabrication and construction, obtain architect and owner's acceptanceof shop drawings in accordance with Caltech Division One Specifications Section 01 3300 — Submittal Procedures.

D. **Samples**: Submit samples specified in applicable sections for components and materials included in mock-up.

E. Certifications

1. Related Contractor and Subcontractor Review and Acceptance Certification: Submit certification specified in Review and Acceptance paragraph in Part 2 of this section under 2.1 General — Mock-ups.

1.4 QUALITY ASSURANCE

A. General mock-up requirements
   1. Purpose of mock-up includes, but is not necessarily limited to, the review of appearance, quality of workmanship, range of aesthetic effects and workmanship, coordination, compatibility, and relationships with adjacent materials, to test user procedure functionality, and to provide contractor with opportunity to coordinate subcontractor work.
   2. Maintain quality control over work of various sections of specifications, manufacturers, products, services, workmanship, and site conditions to produce mock-ups in accordance with the contract documents.
   3. Performance requirements specified for each material shall apply to each mock-up, including tolerances and material properties.

B. Design, engineer, and construct mock-up, including required shoring, bracing, foundations, power, and related requirements.
   1. Comply with performance requirements specified in the individual specification sections.
   2. Maintain design concept, member profiles, and alignment of components.

C. During mock-up assembly, notify architect and owner of conditions that may violate material manufacturer's warranty, installation procedures, or recommendations.

D. Testing Agency Qualifications
   1. Qualified according to ASTM E 329 and E 699 for testing indicated.
   2. Testing agency shall be approved by owner.
   3. Testing agency shall be approved by the authority having jurisdiction (AHJ).

E. Following acceptance, mock-ups shall serve as a performance standard of quality and appearance of the work it represents, including the interface with adjacent materials and components as applicable.
   1. Contractor shall have subcontractors with work affected by the mock-up(s) review the mock-up and agree to certify to meet the standards and quality shown. Submit signed certifications to owner.
   2. Construction of the mock-up assemblies shall be under the supervision of the same personnel who will be employed for the subsequent work.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Coordinate fabrication, delivery, assembly, and installation with related materials included in mock-ups.

1.6 FIELD/SITE CONDITIONS

A. Maintain mock-ups in neat, clean condition until removal or final acceptance. Repair damage as required to maintain in condition suitable for review and approval.

   1. Protect mock-ups as required to permit installation during on-going construction. Provide protective coverings or enclosure as required to secure mock-up from vandalism, theft, and damage until final acceptance, including all testing.

PART 2 - PRODUCTS

2.1 GENERAL – MOCK-UPS

A. **Description of Mock-ups**: Full-size, physical assemblies, constructed on-site, to verify selections made under sample submittals; to demonstrate aesthetic effects and, where indicated, quality of materials and execution; to review construction, coordination, testing, or operation; to show interface between dissimilar materials; and to demonstrate compliance with specified installation tolerances.

1. Construct mock-up using materials complying with performance requirements specified in each applicable section, including tolerances and material properties.
2. Demonstrate proposed range of aesthetic effects and workmanship.

B. **Mock-up Construction/Fabrication:** Before installing portions of construction requiring mock-ups, fabricate or construct mock-ups for each form of construction and finish required to comply with following requirements, using materials indicated for completed construction:

1. Construct or fabricate mock-up with all components and materials indicated for related subsequent construction. Provide engineering services required for construction or fabrication of mock-up.
    a. Construct mock-up at the location and of the size indicated in the contract documents.
2. Construct mock-ups complying with performance requirements specified in applicable individual sections.
3. Maintain design concept of mock-up assembly, including member profiles and alignment of components.
4. Photograph mock-up assemblies at each review stage and distribute clear and well-defined photographs meeting quality requirements specified in Caltech Division One Specifications Section 01 3233, documenting standard of workmanship and construction for observation of subsequent construction.
5. **Scheduling**: Construct mock-ups in timely manner permitting review and modifications without delaying subsequent construction.
    a. Do not proceed with ordering of components for subsequent construction or start until all mock-up assemblies have been accepted, including by architect and owner.
    b. Notify architect and owner seven days in advance of dates and times when mock- ups will be constructed.
    c. Include line item in construction schedule specified in Division 01 for each mock- up, showing submittals, construction, review, and acceptance periods.
    d. Allow sufficient time in schedule to accommodate failures of tests and required modification and retesting of mock-up assembly. Erect mock-up in sufficient time to allow final approval of texture and color of components of mock-up assembly.

C. **Modifications:** Provide modifications required to achieve mock-ups acceptable to architect and owner, meeting testing requirements and demonstrating quality required by contract documents.

1. Approval of mock-ups does not constitute approval of deviations in mock-ups from contract documents unless specifically approved in writing by architect and owner.

D. **Review and Acceptance**: Obtain architect's and owner's acceptance of mock-up assembly before starting fabrication or construction illustrated by mock-up assembly.

1. **Timing**: Provide at least 7 days for initial review of each mock-up assembly phase and at least 7 additional days for review of each revision to mock-up assembly.
2. **Architect and Owner's Review of Partial Mock-ups**: If requested by contractor or owner, review of partial mock-ups does not constitute acceptance of incomplete mock-up construction or mock-up construction not installed. Review of partial mock-ups applicable only for completed work as requested and not for adjacent construction.
3. **Related Contractor and Subcontractor Review**: Arrange for review of mock-up by contractors and

subcontractors whose construction is affected by construction illustrated by mock-up assembly.

a. **Certification**: Obtain written certification from related contractors and subcontractors that construction of mock-up assembly meets standard and quality required for their construction.

4. **Accepted Mock-ups**: Following acceptance, mock-ups provide performance standard of quality and appearance for construction represented by mock-up, including interface with adjacent materials and components.

E. **Incorporation into Subsequent Construction**: Maintain mock-up assembly through completion of building to provide standard for workmanship. Subject to compliance with requirements, accepted mock-ups may be incorporated into subsequent construction if undisturbed at substantial completion.

2.2 LAB CLASSROOM MOCK-UP ASSEMBLY 1

A. **Mock-up Assembly 1 Description**: Mock-up of typical interior lab classroom constructed in place and in stages, as an accelerated mock-up complete with wall, floor, and ceiling finishes, doors, windows, millwork, casework, specialties, furnishings and equipment, and lighting.

1. Provide a full-scale mock-up of typical laboratory spaces for a three stage (rough-in, templates, and finish) review by owner. The laboratory mock-up shall include all materials including basic peninsula, basic wall units, fume hood, and utility lines. The actual utilities and equipment do not need to be functional or energized, unless specified otherwise.
2. Construct mock-up 1 within building shell at location selected by contractor and approved by owner.
3. In the event that problems with coordination of work of different trades become apparent during the construction and review of the mock-up and result in design changes, owner shall be responsible only for replacement of work in the actual mock-up construction that satisfies the original design and quality requirements as indicated in the contract documents. The contractor shall be responsible for replacing, without alteration of the contract sum or the contract time, any such work outside the extent of the mock-upthat is provided before approval of the mock-up construction, and which must be replaced due to design changes resulting from the mock-up review.
4. Comply with requirements specified in individual sections in Divisions 03 through 33 applicable to mock-up including related supporting components, including materials and assemblies indicated and finished as specified in individual sections.
5. Provide required lighting and additional lighting as required to enable architect and owner to evaluate room mock-up.

B. **Mock-up Sequence**:

1. **Stage 1**:
   a. Floor / ceiling shell structure complete
   b. Wall framing enclosing room complete
   c. Plumbing rough complete, with valves and stub-outs for all connections of all systems. Label all functions.
   d. Back boxes rough complete: Electrical, data, communication, and AV, including pullboxes, device junction boxes, and controls. Label all functions.
   e. Fire sprinkler piping, including head locations
   f. Mechanical hydronic piping and air distribution (supply, return, and exhaust drops), as applicable
   g. Backing and blocking for finish and equipment elements attached to wall surface, based on drawings
2. **Stage 2**:
   a. Gypsum board finish, taped, and textured, unpainted
   b. Lab equipment, lab fittings, light switches, plumbing fixtures, furniture, and casework/cabinet representations in fire-rated foam or cardboard, pasted/screwed to surface and marked on sub-floor
   c. Access panels for all valves, shutoff controls
   d. Window and glazing representation as required for interior glazing
   e. Door frames
   f. Door swing radius marked on flooring

3. **Stage 3**:
   a. Finish flooring and finish ceiling, including specialty floor, wall, and ceiling finishes such as epoxy/resin systems.
   b. Final wall finish, including paint, in selected colors.
   c. Doors and door hardware, complete
   d. Laboratory casework, countertops of each type, drawer units, cabinets, shelving, sinks with all fittings/fixtures, lab gas/utility outlets, markerboards, tech desks, wire mold, and splash guards
   e. Window covering
   f. Partition closure on exterior wall
   g. Light fixtures and under-cabinet task-light fixtures, with specified lamps, fully energized and operational from switch as designed
   h. Sprinkler heads, fire alarm horn/strobe, and smoke detector
   i. Mechanical air diffuser, registers, grilles
   j. Equipment; except owner-furnished equipment
   k. Acoustic insulation
   l. Light switches, electrical outlets, temperature and humidity sensors and controls, telephone and data outlets, intercom speakers, and all weather-resistant covers
   m. All access panels, diffusers, and grilles
   n. Room furniture

C. **Evaluation and testing**: At each stage, owner and architect will evaluate function and location of mock-up elements. Where required, relocate, or modify the following elements prior to construction of next stage.
   1. Anchorage: As required for seismic compliance
   2. Emergency access to utility shutoffs
   3. Security of lab equipment
   4. Functional reach ranges and proximities

2.3 MATERIALS

Incorporate materials required for mock-up as specified in applicable sections of Division 02 through Division 33.

2.4 FABRICATION

Do not fabricate mock-up until acceptance of submittals required in applicable sections in Divisions 02 through 33 for all materials incorporated into mock-ups. Include in project schedule specified in Caltech Division One Specifications Section 01 3200 – Construction Progress Documentation early submittal of components required for mock-up.

PART 3 - EXECUTION

3.1 EXAMINATION

Verification of Conditions: Examine conditions where mock-ups are to be constructed and notify architect and owner of conditions that may violate manufacturer's warranty, installation procedures, or recommendations for any component in mock-up. Do not begin fabrication or installation of mock-up until unsatisfactory conditions have been corrected. Beginning fabrication or installation indicates acceptance of existing conditions.

3.2 CONSTRUCTION / FABRICATION OF MOCK-UPS

A. Arrange for mock-up assemblies to be constructed by installation personnel who will install subsequent construction under supervision of same personnel that will supervise subsequent construction illustrated by mock-up.

B. Ensure personnel representing manufacturers, fabricators, and installers of mock-ups are present during mock-up construction and testing for efficient evaluation and revision if required.

3.3 FIELD QUALITY CONTROL

A. Review of Mock-up

1. Notify architect and owner at start of mock-up construction or fabrication and submit mock- up construction progress reports to allow architect and owner to schedule reviews.
2. **Sequence of Mock-up Review**: Arrange review of mock-ups insequences:
   a. **Integrated Interior Mock-ups**: Construct Mock-up 1 in sequence as specified in 2.2B.
3. Schedule completion and revision of mock-ups necessary to obtain acceptance to avoid delay in project construction schedule.

B. **Testing**: Conduct tests of mock-ups in presence of owner, architect, contractor, and all related installers. Proceed with each test only after acceptance of detailed test procedure. Conduct tests as indicated for each mock-up.

1. Provide testing as specified in applicable sections in Division 02 through Division 33 for mock-up components and mock-up assembly.

C. **Mock-up 1 Testing Scope**:
1. Anchorage: Testing criteria as required per project.
2. Emergency access to utility shutoffs

D. **Test Report**:
1. **Photographs**: Take photographs at locations and intervals as indicated for each mock-up. Submit digital color images of mock-up before, during, and after testing and include these images in test report. Comply with requirements of Caltech Division One Specifications Section 01 3233 – Photographic Documentation.
2. **Details of Test Results**: List test results in order of testing and document all tests required by mock-up criteria in test report stating each of the following:
   a. Test results achieved.
   b. Any revisions made to test specimen to achieve reported test results; graphically describe on mock-up shop drawings.
   c. Testing dates.
   d. Failure analysis as appendix to test report indicating any corrective action taken to achieve compliance with specification.

E. **Corrective Measures**: Correct any deficiencies in mock-up observed during testing and repeat tests as required to show compliance with specified performance requirements and contract documents. Resubmit any submittals affected by corrections and resubmit shop drawings with changes made to assemblies to successfully complete preconstruction testing.

1. Deficiencies requiring repair or modification to mock-up require complete retesting of mock- up. If compliance with specified performance requirements is not achieved after 2 complete retests, replace mock-up completely with revised construction and start testing from beginning.
2. Incorporate corrective measures indicated by test report into final construction based on documentation provided by architect.

F. **Acceptance of Mock-up**: Obtain acceptance of mock-up in writing based on successful testing results and completed test report.

3.4 DISPOSAL

When authorized by owner, demolish and remove all components of composite mock-ups from project site.

Section 01 45 00 — Quality Control

1. **Overview:**
   - **a.** Administrative and procedural requirements for quality assurance and quality control.
   - **b.** Testing and inspection services are required to verify compliance with requirements specified or indicated. These services do not relieve contractor of responsibility for compliance with the contract document requirements.
   - **c.** Contractor shall maintain quality control over suppliers, manufacturers, products, services, site conditions, and workmanship to produce work of specified quality.

2. **Performance Requirements:**
   - **a.** Submittals
     - **1** Quality Representative Qualifications
     - **2** Quality Assurance (QA) Plan
     - **3** Certificates
     - **4** Monthly Performance Report
   - **b.** Quality Control
     - **1** Quality Representative Qualifications
       - **i.** Submit to the contracting officer for approval. Quality representative may be assigned to more than one contract provided that the assigned contracts are located at the same site.
       - **ii.** Designate a quality program manager within the on-site organization whose sole responsibility is the day-to-day on-site management and direction of the quality program.
     - **2** Quality Control Records
       - **i.** Maintain quality control records at a central on-site location. Maintenance of quality control records does not provide relief from submitting samples, test data, detail drawings, material certificates, or other information required by each section in the specification. Ensure that each record is identified and traceable to specific requirements in the specifications and drawings.
     - **3** Caltech Inspections
       - **i.** Work performed under this contract is subject to inspection by Caltech.
       - **ii.** Notify Caltech in writing before backfilling or encasing any utilities so that work may be inspected. Failure to notify Caltech before backfilling or encasement occurs will require the work to be uncovered at no additional cost to Caltech.

3. **Product Requirements:**
   - **a.** Quality Assurance (QA) Plan
     - **1** Submit a QA plan that addresses the following:
       - **i.** Description of the authority, responsibilities, and coordinating procedures of on-site/off-site quality assurance personnel, including those QA personnel not under direct control of the contractor.
       - **ii.** List of personnel designated to accomplish the work required by the contract.
       - **iii.** The operational plan for establishing and reviewing work controls, fabrication controls, certifications, and documentation of quality control operations, inspections, and test records, including those for subcontractors.
       - **iv.** The methods used during the procurement cycle (order to delivery) for those materials or equipment that require source inspections, shop fabrications, or similar operations located separately from the work site.
       - **v.** Description of on-site personnel training.
       - **vi.** Certifications of personnel, procedures, processes, and equipment.
       - **vii.** Nondestructive testing (NDT) requirements.
       - **viii.** Identification of independent certifying and testing laboratories.
   - **b.** Monthly Performance Report
     - **1** Submit a monthly summary of the quality operations. Identify inspections made, tests performed, nonconformances found, corrective actions taken, status of plans/procedures being developed, and status of open items/problems in work.

Section 01 56 00 — Temporary Barriers and Enclosures

1. **Temporary Fencing:**
   - **a.** If specifically instructed by Caltech, contractor shall provide barriers to prevent unauthorized entry to construction areas. Provide minimum 6-foot- or 8-foot-high chain-link fencing as deemed by Caltech with green privacy fabric and/or as specified by the jurisdiction. Provide covered and sufficient walkways as required to protect adjacent pedestrian walkways with proper clearance.

2. **Temporary Security Barriers:**
   - **a.** Guard machinery, equipment, and all hazards in accordance with the safety provisions of the authorities having jurisdiction. Protect all hazards with adequately constructed guardrails or barricades and provide lanterns, warning lights, proper signage, and the like, as necessary to maximize safety. To this end, dispose, store, guard, and protect the premises and all work, material, equipment, and both permanent and temporary construction to preclude the unauthorized use thereof and eliminate possible consequent injury to all persons.
   - **b.** Obtain approval from Caltech Security prior to installation of any temporary security cameras or video surveillance systems. Submit camera make, model, and proposed locations for review. Provide appropriate surveillance signage as required by Caltech Security and remove all temporary equipment and signage at project completion.
3. **Temporary Tree and Plant Protection:**
   - **a.** Exercise extreme care to preserve and protect all existing trees on campus from damage of any kind.
   - **b.** Notify Caltech in advance of any conditions that require vehicles or equipment to operate within the spread of trees.
   - **c.** Protect tree roots from damage as directed by Caltech. Coordinate with Caltech PM and Grounds for tree protection plan.
     - **1)** Do not place materials, debris, earth, vehicles, or temporary structures under spread of trees.
     - **2)** Do not dump excess concrete, chemicals, or other liquid waste on campus grounds, landscaped areas, or into storm drains.
     - **3)** Do not operate vehicles or equipment within the spread of any trees.
   - **d.** The design team or design builder will advise the contractor of protective measures, such as planking, that must be followed to avoid damage to root, trunk, and branch structures where contract work must be performed in the vicinity of trees. Necessary protective measures may include some or all of the following:
     - **1)** The contractor may build fences around the trees to be protected. These fences should be built along the drip line, or as close to the drip line as the construction activity will allow, and should remain in place throughout construction duration.
     - **2)** Any required branch or root pruning should be performed under the direction of Caltech's project manager and other Caltech representatives.
     - **3)** When trenching occurs around trees to remain, the roots should be carefully exposed by hand-digging to reveal the nature of branching and then either tunneled under or carefully and precisely cut under the direction of the design professional.
     - **4)** When excavating, digging, or setting pilings within a tree drip line, the contractor shall carefully dig pilot holes a minimum of 3 feet deep prior to driving the piles.
     - **5)** Trees marked for preservation that are located more than 6 inches above proposed grades should stand on broad rounded mounds and be graded smoothly into the lower level. Exposed or broken roots should be cut cleanly and covered with topsoil.
     - **6)** Existing trees in areas where the new finished grade is to be lowered should have regrading work done by hand to the elevation as indicated. Roots shall be cleanly cut as required 3 inches below finish grade and covered with topsoil.
     - **7)** The contractor shall take care when working around the head of a tree. If any pruning is necessary, the pruning procedure must be supervised by the design professional.
     - **8)** The contractor shall be responsible for replacing any existing trees as determined by either Caltech and/or jurisdiction that are damaged as a result of work under the contract.
     - **9)** In the case that it is deemed by Caltech that irreparable damage has been done to any tree or trees, their value shall be determined in accordance with Caltech and/or the International Society of Arboriculture's Guide for Plant Appraisal, current edition.
4. **Temporary Site Management and Housekeeping:**
   - a. Provide and maintain adequate refuse containers for construction debris. Disposal of construction materials, packaging, and waste in Caltech trash or recycling receptacles is prohibited.

b. Provide contractor restroom facilities for the duration of construction. Building restrooms and sinks shall not be used by construction personnel for routine use or for cleaning tools, equipment, or materials.
c. Maintain construction, staging, and parking areas in a clean condition. Do not litter or leave debris on the ground.
d. Do not park vehicles, equipment, or material storage on landscaped areas. Repair or replace in kind any items damaged by construction activities.
e. Remove temporary utility location markings from concrete, paving, and other exposed surfaces at project closeout. Restore surfaces to original condition if markings cannot be completely removed.
f. Temporary floor protection shall be installed in a manner that does not damage existing finishes. Upon removal, all tape, adhesive, and residue shall be completely removed from floor surfaces.

Section 01 58 00 — Project Identification

1. **Signage.** Contractor shall provide signs as follows:
   a. Painted, 5-foot-wide by 3-foot-high project sign of 3/4-inch-thick, exterior grade, A-C plywood with self-adhesive, die-cut vinyl letters to design professional's design and colors, and wood frame construction.
   b. Coordinate with Caltech PM on signage design standard and sign locations. Graphic image shall be furnished by design professional following Caltech standard. All text should be legible, drawings to be 'presentation style,' easily legible by the public. List title of project team members including but not limited to: Names of Caltech personnel, design professionals, mechanical consultant, plumbing consultant, electrical consultant, structural consultant, and contractor.
   c. Erect on site at locations to be determined by Caltech.
   d. No other signs are allowed without Caltech permission except those required by law.
   e. Caltech shall review all signage prior to posting. Contractor shall send drawings of signage for review.

Section 01 78 00 — Closeout Submittals

1. **General:**
   a. The design-build team, including consultant(s), shall provide project progress and deliverables as outlined below. Final payment or retention shall not be approved until all required data, documents, and drawings are both received and verified to meet contract requirements.
2. **Deliverables:**
   a. The construction contractor or design builder (including subs and/or consultants) shall furnish all data, documents/files, and drawings customarily required or expressly required throughout the project. Deliverables shall be received in accordance with the construction agreement and the project closeout checklist (See Appendix III, Project Closeout Checklist) tracked via the submittal register. The submittal register shall be created and maintained by the construction contractor and available to Caltech at all times. All submittals shall be listed and tracked on the submittal register. HVAC Equipment and Control Points shall be named per the Caltech Asset and BMS Naming Standards.
3. **Spare Parts and Attic Stock:**
   a. Provide Caltech products, spare parts, operations and maintenance manuals, and extra materials in quantities specified in individual specification sections. The contractor shall deliver material to the project site and place in location as directed by the Caltech project manager and shall provide transmittal listing the products provided prior to final payment.
      1) Materials and items requiring spare parts and extra quantities (this is a limited list and not intended to be a full list of required spare parts and attic stock):
         i. Door hardware
         ii. **Ceramic, stone, porcelain tile, travertine, pavers, material on the skin of building**: 1% of quantity installed
         iii. **Wood flooring**: 1% of quantity installed
         iv. **Resilient flooring** (including Linoleum): 10 linear feet for every 500 linear feet or fraction thereof of quantity installed; in roll form and in full roll width for sheet flooring
         v. **Acoustical ceiling panels and suspension system**: 1% of quantity installed

vi. **Paint**: Provide specifications only
vii. **Carpet** (including carpet tile): 1% of quantity installed, but not less than 5 sq. yd. Provide full-size units of carpet tile; full-width rolls for broadloom carpet.
viii. **Access flooring** (including panels, pedestals, and stringers): 1% of quantity installed. Provide full-size panels
ix. **Resilient base and accessories**: 10 linear feet for every 500 linear feet or fraction thereof, of quantity installed
x. **Wallcoverings**: 5 linear yards of quantity installed, in full roll width

2) Provide list of subcontractors, including contacts, to Caltech project manager.

3) Provide list of finishes and vendors of the following items to the Caltech project manager in one document. This is in addition to submittals required by the appropriate specification section. Organize the information by room or by space to simplify Caltech reference for future repair or renovation work:

i. Paints, carpets, wall base, ceiling tiles, resilient flooring, furnishings (incl. furniture list, millwork, and furniture finishes), equipment, lighting, etc.

4. Closeout Deliverable Documents:

a. Prior to final payment, the contractor/consultant shall provide a copy of all documents and drawings customarily required of the contractor, as a part of or prior to the project closeout. Deliverables shall including, but are not limited to, the following documents: (1) detailed and comprehensive as-built drawings depicting actual field conditions, (2) operations and maintenance manuals, (3) warranties, (4) specifications/guidelines, (5) structural calculations (where applicable), (6) shop drawings, (7) site/soil surveys (where applicable), (8) air balance reports, (9) commissioning reports/logs including equipment calibration details and set points, (10) other record documents as customarily required, and (11) all RFIs and submittals submitted and responded to throughout the project. See list below for more detail:

Closeout Documents	Document Details	Format
Final Punch List		PDF
Permits and Certifications	All permits	PDF (bound into one PDF)
Training	All training materials	Video
Test Reports/Certifications	Certificate of Substantial Completion	PDF
Test Reports/Certifications	TAB Test Report	PDF, Excel
Special Inspection Reports	Submitted in one bound PDF	PDF
Drawings	As-Builts	PDF, CAD, and Revit where applicable
Drawings	Approved Permit Set	PDF, CAD, and Revit where applicable
Asset Management	See commissioning guidelines for requirements	
O&M Manuals	Manuals submitted individually and in one bound PDF	PDF (Bound in one PDF and individually)
Warranties	All warranties, submitted individually and in one bound PDF	PDF (Bound in one PDF and individually)
Submittals	All Approved Submittals (including product data, shops drawings, etc.)	PDF (bound in one PDF)
RFIs	All project RFIs	PDF (bound in one PDF)
Updated Room and Cost information	Provide information for all room square footages and cost breakdown by room	Excel (template provided by Caltech PM)
Attic Stock	Coordinate with Caltech PM and submit proof of delivery	PDF (Proof of Delivery and signature by Caltech)
Spare Parts	Coordinate with Caltech PM and submit proof of delivery	PDF (Proof of Delivery and signature by Caltech)
Photos	Refer to “Photographic Documentation Requirements” for project, including before, progress, and finished project photos	JPEG, JPG, see “Photographic Documentation Requirements”

5. All Closeout documents shall comply to the following requirements to allow easy retrieval and cross reference of each document:

a. File content and naming of each individual document shall be identical (or significantly similar) to the same document delivered in a different file format (e.g. ACAD drawing vs. PDF document vs. Word document, etc.).

b. File names shall be created that produce a properly sorted set of documents (e.g. MEP drawings 01–23, O&M manual sections A–Z, etc.).

c. All electronic closeout deliverables shall be provided with appropriate labeling to include project name, building name, and date (e.g., vendor/consultant name, Caltech building number, Caltech project #, etc.)

Section 01 81 00 — Sustainable Design Requirement Renewable Energy

Caltech encourages the incorporation of renewable energy generation and energy storage systems in new construction and major renovations where technically and financially feasible. Project teams shall evaluate opportunities for on-site renewable energy integration and coordinate with Caltech Facilities and Sustainability during design.

DIVISION 02 – EXISTING CONDITIONS

Section 02 41 00 - Demolition

1. **General:**
   - **a.** Perform the work of this section by workers skilled in the demolition of buildings and structures.
   - **b.** Perform the work of this section under direct supervision at all times.
   - **c.** Prior to commencement of work, schedule a walkthrough with the owner, to confirm campus property items have been removed from scheduled work areas. Identify and mark remaining property items and schedule their removal.
   - **d.** Coordinate with Caltech PM and Caltech asset manager for all assets identified for demolition. Provide an asset tag list of all assets scheduled for decommissioning and demolition. DO NOT DEMO assets without informing Caltech PM and Caltech asset manager.
     i. Prepare a demo plan and get it approved by Caltech PM and asset manager. Record all assets to be demoed on a demo plan, including location, asset ID, and timeline of demo.
   - **e.** Coordinate demolition for the correct sequence, limits, and methods. Schedule demolition work to create the least possible inconvenience to Facilities.
   - **f.** Drawings may not indicate in detail all demolition work to be performed. Examine existing conditions to determine the full extent of required demolition.
   - **g.** Repair damage to existing improvements or damage due to excessive demolition.
   - **h.** Provide all measures to avoid excessive damage from inadequate or improper means and methods, improper shoring, bracing, or support.
   - **i.** If conditions are encountered that vary from those indicated, promptly notify the project manager for clarification before proceeding.
   - **j.** Do not commence demolition until safety partitions, barricades, warning signs, and other forms of protection are installed.
   - **k.** Provide safeguards, including warning signs, lights, and barricades, for protection of workers, occupants, and the public.
   - **l.** If safety of existing construction appears to be endangered, take immediate measures to correct such conditions; cease operations and immediately notify Caltech project manager.
   - **m.** Where openings are cut oversize or in improper locations, replace or repair to required condition.
   - **n.** Cutting of existing concrete shall be performed by skilled workers familiar with the requirements and space necessary for placing concrete. Perform concrete cutting with concrete cutting wheels and hand chisels. Do not damage concrete intended to remain.
   - **o.** Extent of cutting of structural concrete shall be as indicated on drawings. Cutting of nonstructural concrete shall be as indicated on drawings or as reviewed by the architect or structural engineer. Replace concrete demolished in excess of amounts indicated.
   - **p.** Prior to cutting or coring concrete, determine locations of hidden utilities or other existing improvements and provide necessary measures to protect them from damage.
   - **q.** Patch or repair materials to remain when damaged by the performance of the work of this section. Finish material and appearance of patch and/or repair work shall match existing.
2. **Handling of Materials:**
   - **a.** Items scheduled for salvage by Caltech shall be delivered to a location designated by the project manager. Items shall be cleaned, packaged, and labeled for storage.
   - **b.** Items scheduled for reuse shall be stored on the project site and protected from damage, theft, and other deleterious conditions.
   - **c.** Do not throw or drop materials. Furnish ramps or chutes as required by the work.
   - **d.** Remove existing construction only to extent necessary for proper installation of work and interfacing with existing construction. Cut back finished surfaces to straight, plumb, or level lines as required for a smooth transition.
   - **e.** Maintain 36–inch minimum clearance in corridors for egress if materials will be temporarily stored.

3. **Cleaning:**
   a. Clean existing materials to remain with appropriate tools and equipment.
   b. Protect existing improvements during cleaning operations.
   c. Debris shall be dampened by fog water spray prior to transporting by truck.
   d. Debris pickup area shall be kept broom-clean and shall be washed daily with clean water.
   e. Remove waste and debris, other than items to be salvaged. Turn over salvaged items to project manager, or store and protect for reuse where required. Continuously clean up and remove items as demolition work progresses.

Section 02 41 16 - Structure Demolition

1. Completely remove foundations and other sub-grade construction associated with a structure indicated to be demolished.
2. Controlled demolition by mechanical means is the preferred method. Obtain written permission from Caltech and authorities having jurisdiction before bringing explosives to, or using explosives on, project site. Document conditions of adjacent structures when collateral damage is possible. Seismographic monitoring may be required on adjacent structures.

Section 02 41 19 - Selective Demolition

1. Comply with the City of Pasadena Municipal Code, Chapter 8.62, Ordinance No. 6917 “Construction & Recycling Ordinance.” Complete and submit permit application, fees, reports, and other documentation as required by local authorities.
2. Prior to demolition activities, coordinate a site walk with the Caltech Project Manager, Recycling & Materials Coordinator, Recycling Lead, and Transportation Supervisor to identify materials and equipment designated for reuse, salvage, recycling, storage, resale, or disposal. Materials designated for salvage or resale will be removed by Caltech Transportation as part of project cost. Contractor to remove remaining demolition waste and provide waste diversion documentation at project closeout.
3. Conduct demolition operations in a manner that avoids interference with Caltech’s operations of the occupied project building as well as the adjacent occupied buildings.
4. Coordinate with Caltech project manager and building administrator to mitigate noise, dust, fumes, and vibration concerns.
5. Provide temporary protective barriers, such as fences, railings, canopies, and covered passageways, to ensure safe passage of people around demolition area.
6. Protect existing adjacent buildings, facilities, site improvements, appurtenances, and landscaping indicated to remain.
7. Maintain entry and exit access from adjacent buildings.
8. Do not close or obstruct streets, walks, walkways, or other adjacent occupied or used facilities without permission from Caltech and authorities having jurisdiction. Provide alternate routes around closed or obstructed trafficways if required by authorities having jurisdiction.
9. Utilize suitable methods to limit spread of dust, dirt, and noise. Comply with governing environmental protection regulations.
10. On-site storage or sale of removed items or materials is not permitted.
11. Maintain existing utility services indicated to remain and protect them against damage during demolition operations. Provide at least 72–hour notice to Caltech Planning, Design & Construction Department if shutdown of service is required.
12. Provide temporary services/systems that bypass utility services/systems that are to be demolished or relocated in order to maintain continuity of services/systems to other areas of the campus. Do not interrupt existing utilities serving occupied or operating facilities unless authorized in writing by Caltech.
13. Transport demolition waste materials from project site in a manner that will prevent spillage on adjacent surfaces and areas, and legally dispose of them in an Environmental Protection Agency (EPA)-approved landfill acceptable to authorities having jurisdiction.

Section 02 80 00 - Facility Remediation

1. **Hazardous Material Abatement:**

a. Demolition, renovation, or remodeling projects are likely to involve some hazardous material abatement. Prior to construction, Caltech will provide current information on identified hazardous materials on site. If current information does not exist, or if demolition, renovation, or remodeling activities may disturb building materials not previously evaluated, perform hazardous material surveys and testing by an independent, certified testing contractor prior to the start of construction. If testing identifies the presence of hazardous materials, a HazMat licensed contractor shall be contracted for abatement. If hazardous material is suspected or found after the start of construction, promptly report to the Caltech project manager, Caltech EH&S and possible outside agencies for further direction.

b. Coordinate asbestos-related remediation activities with Caltech EH&S and comply with the Caltech Asbestos Management Program . Coordinate required regulatory notifications with Caltech EH&S and applicable regulatory agencies, including SCAQMD, as required by the scope of work. Contractor to schedule Caltech EH&S review of hazardous waste manifest prior to shipment and obtain required sign-offs before waste transfer. Provide all documents required by EH&S to support hazardous material abatement closeout and completion of required project closeout documentation.

c. For asbestos abatement work impacting high-traffic occupied offices, laboratories, or other sensitive environments, provide independent third-party oversight by a certified asbestos consultant (CAC). The CAC shall perform project monitoring, visual inspections, and air monitoring or clearance sampling, as appropriate for the scope of work, prior to re-occupancy or release of the area.

d. For lead abatement work impacting high-traffic areas, occupied offices, laboratories, or other sensitive environments, provide independent oversight by a CDPH-certified lead professional. Monitoring, inspections, and lead dust wipe clearance sampling shall be performed as required by Caltech EH&S, applicable regulations, and project-specific conditions prior to re-occupancy or release of the area.

e. See link to Caltech Safety guidelines: http://safety.caltech.edu/manuals

Section 02 82 00 - Asbestos Remediation

1. Clearly mark and label all emergency exits located within the regulated area. Emergency exits shall be kept free of obstructions at all times. A razor knife or other cutting tool shall be posted in the vicinity of each emergency exit located within the regulated area and used to facilitate quick exit of the work area in an emergency situation.
2. Receive authorization from the owner or owner's representative prior to initiating any asbestos removal activity. Caltech representative shall conduct a pre-abatement inspection to ensure compliance with the design guidelines prior to authorizing start of any asbestos removal activities.
3. Inspect the integrity of all regulated area barriers and smoke test for leaks at the beginning of each shift. Any detected leaks shall be sealed prior to start of work.
4. Maintain a log of all personnel entering the regulated area. The contractor shall not allow any person to enter the regulated area without prior approval of owner or owner's representative. This includes contractor employees newly assigned to the job site.
5. Provide authorized visitors with protective clothing, whenever they are required to enter the regulated area.
6. Ensure that each worker and authorized visitor shall follow the approved procedures established by the contractor and Caltech.
7. Perform all work, regardless of exposure, using HEPA vacuuming and wet methods. Promptly clean up and dispose of asbestos in leak-tight containers. Remove all existing asbestos-containing building materials identified within the project scope of work. Construct, install, and otherwise secure all barriers in a manner that will ensure that they remain intact and serviceable throughout the duration of the project. All abatement work shall be halted in the event of any barrier breach. Breaches shall be immediately corrected/repaired, and no work shall recommence until approved by a Caltech representative. Adequately wet asbestos-containing materials (ACMs) to be removed prior to stripping and/or tooling to reduce fiber dispersal into the air. Accomplish wetting by a fine spray (mist) of amended water or removal encapsulate. Saturate material sufficiently to wet to the substrate without causing excess dripping. Allow time for water or removal encapsulate to penetrate material thoroughly. Spray material repeatedly during the work process to maintain a

continuously wet condition. Mist work area continuously with amended water whenever necessary to reduce airborne fiber levels.

8. Waste shall be packaged prior to each break and at the end of each shift. If applicable, contractor shall make arrangements with Caltech to store ACM waste in a secured area until waste can be removed from the job site.
9. Ensure that the level of respiratory protection worn by contractor's employees is adequate to protect the employees from exposure to airborne asbestos fibers above the permissible exposure limits. Ensure airborne asbestos fiber levels inside the work area do not exceed a ceiling limit of 1 fiber per cubic centimeter (f/cc), as determined by personal or area air sampling, regardless of the level of respiratory protection worn by contractor's employees. If this level is exceeded, contractor shall take immediate action to reduce airborne fiber concentrations. If this level is exceeded for 2 consecutive shifts, the contractor shall cease asbestos removal operations and perform necessary cleanup to reduce the airborne asbestos fiber level to below 0.2 f/cc as indicated by subsequent air samplings.
10. Conduct personal exposure monitoring and provide monitoring results within 24 hours after samples are collected to Caltech or Caltech's representative. Notify owner or owner's representative immediately in the event of a breach of the containment barrier or spill of ACM outside of the regulated area. Take protective measures to ensure occupants adjacent to the spill or breach are not exposed to asbestos. In the event of a breach of the containment barrier or spill of ACM outside of the regulated area, immediately stop work, repair the breach and clean up the spilled material using wet methods and HEPA vacuuming.
11. In the event that a non-work area becomes contaminated with asbestos, the contractor shall immediately and automatically stop all work. If the contaminated area is inside the building and outside of critical barriers, the contractor shall erect new critical barriers to isolate the affected area from the balance of the building. Erect critical barriers at the next existing structural isolation of the involved space (e.g., wall, ceiling, floor, etc.). Decontaminate the affected area in accordance with this specification. Leave critical barriers in place until final visual and air clearance is given.
12. The contractor shall perform all required cleaning and/or decontamination at no additional cost to Caltech.
13. The contractor shall not encapsulate abated surfaces until the work area has passed final inspection as determined by Caltech's representative.
14. **Decontamination facilities (entering and exiting the regulated area**): The contractor shall ensure that all authorized personnel enter and exit the regulated area through the decontamination facility. Decontamination facilities shall be provided at all location(s) where workers enter or exit the work area. These facilities will be placed at the most strategic location(s) to allow easy access and usage while maintaining the ability to secure the building during non-working hours.
15. Decontamination facilities must be of sufficient size as to accommodate cleaning and decontamination of all personnel, equipment, and materials passing through the regulated area.
16. **Asbestos Abatement**: All items and personnel that enter the regulated area must exit through the decontamination facility. Affected items/personnel, including tools, equipment, supplies, personal protective equipment, packaged waste, etc., shall be cleaned before exiting the decontamination facility so that contamination cannot be spread beyond the regulated area. The employer shall ensure that employees enter and exit the regulated area through the designated decontamination room or area.
17. See Caltech Safety guidelines. http://safety.caltech.edu/manuals

Section 02 83 00 - Lead Remediation

1. When active lead abatement work is taking place, there shall be continuous, ongoing cleanup to reduce the accumulation of debris, and the work site shall be cleaned at the end of each day's activities.
2. Prior to beginning lead control, all stored materials or equipment shall be either removed to a "clean room" or wrapped in polyethylene prior to start of the lead abatement work. A separate, secured area within the containment space shall be designated for storage of debris until it can be properly disposed of according to the contract documents.
3. The lead abatement area shall be secured to prevent entry by any persons after termination of the workday. Disposable supplies such as mop heads, sponges, and rags shall be replaced regularly and disposed of according to the lead-based paint (LBP) specifications. Durable equipment, such as power and hand tools, generators, and vehicles, shall be cleaned monthly or more frequently as needed based on the level of lead contamination and use.

4. All equipment shall be cleaned by HEPA vacuuming and detergent washing. All cleanup procedures shall be completed prior to removal of containment barriers and temporary protections.
5. **Cleanup Methods and Equipment**: Areas in which lead abatement operations have been completed shall be cleaned, starting at the ceilings and working down to the floors, by vacuum cleaning using a HEPA vacuum, followed by a wet cleaning with a general, all-purpose cleaner or a cleaner made specifically for lead. After spraying the surface, a wet and dry HEPA vacuum shall be used to vacuum the water from the surface.
6. **High Efficiency Particulate Air (HEPA) Vacuum**: The contractor will obtain training in the use of the HEPA vacuum from the manufacturer prior to use. The contractor shall obtain HEPA vacuum attachments, such as various sized brushes, crevice tools, and angular tools to be used for varied application, and service the HEPA vacuum routinely to assure proper operation. Caution shall be taken any time the HEPA is opened for filter replacement or debris removal. Operators shall wear a full set of protective clothing and equipment, including respirators, when using the HEPA vacuuming equipment. Protective clothing and equipment shall be removed prior to leaving the work area.
7. See link to Caltech Safety guidelines: http://safety.caltech.edu/manuals

Section 02 87 13 - Mold Remediation

1. Physical separation and engineering controls are required to prevent contamination of undamaged materials and occupied areas. The level of containment varies depending on the extent of the contamination.
2. **Floor protection**. Maintain protection for finished floors through all construction activities. HEPA vacuum to control dust created during the demolition. Hold HEPA vac intake at source of dust.
3. **Unoccupied Building Containment.** Use when a building is unoccupied and large amounts of mold growth are present throughout the building's containment.
4. The containment consists of the entire building. Install air filtration units (AFUs) with HEPA filters in the building. Configure the AFUs to recirculate within the active remediation area. AFUs shall filter a minimum of four air changes per hour and a maximum of six air changes per hour based on the size of the area undergoing active remediation.
5. **Isolation of Work Areas**. Install polyethylene barriers to isolate the areas where remediation is not required. AFU discharge may be used to positively pressurize non-remediation areas from areas undergoing remediation to prevent the movement of spores into clean areas.
6. **Floor Protection**. Maintain protection for finished floors through all construction activities.
7. **Protection for all items remaining in the containment**. Protective devices shall prevent physical damage (e.g., scratches and dents) and shall provide a positive seal to prevent dust from settling in or on the items.
8. **Decontamination**. Construct a decontamination airlock for entry into and exit from the building.
9. **Containment Entrance**. A triple-flap poly door shall be used at the entrance to the work area during demolition to minimize egress.
10. **Cleaning Containment**. A temporary containment structure set up to clean items removed from the containment shall be erected. At a minimum, the cleaning area shall contain 2 chambers.
11. **Cleaning Chamber.** Construct walls with polyethylene. Items will be cleaned in the first chamber. The clean items shall be stored in the second chamber.
12. **Air Filtration / Pressurization Control Cleaning Chamber**. Install AFUs with HEPA filters in the cleaning chamber. Configure the AFUs with splitters / diverters to allow some of the air to recirculate within the containment storage chamber. The AFUs shall be configured to maintain the required airflow and pressure differentials within the containment area.
13. **Decontamination Unit (Airlock).** An enclosed area adjacent to and connected to a regulated work area that is used for the decontamination of workers, equipment, and materials.
14. **Dehumidifier**. Mechanism or machine to remove moisture from the air.
15. **Detergent cleaning agent**. The term refers to a prepared compound that may include surfactants, detergent builders, dry solvents, softeners, etc., but does not include true soap.
16. **Disinfectants or Biocide Sanitizing Solutions.** One of three groups of antimicrobials registered by the EPA for public health uses. The EPA considers an antimicrobial to be a disinfectant when it destroys or irreversibly inactivates infectious or other undesirable organisms, but not necessarily their spores.

17. **Fungicidal Agents**. A coating material that contains an EPA-registered fungicide that inhibits the spread and growth of mold with the ability to withstand moist and humid conditions.
18. See link to Caltech Safety guidelines: http://safety.caltech.edu/manuals

DIVISION 03 – CONCRETE

Section 03 30 00 – Cast-In-Place Concrete

1. **Overview:**
   a. Cast in place structural concrete and non-structural concrete.

2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
   b. Sustainability
   c. Submittals
      1) Mix Designs:
         i. Submit proposed concrete mix designs for each class or use at least 30 days prior to required delivery.
         ii. Mixes shall be prepared by a professional engineer licensed in the state in which the project is located; a certificate signed and stamped by a PE shall be provided.
         iii. Provide drawings indicating specifically where each class of concrete is to be used. Identify each mix design with code number that will be used on batch tickets.
         iv. Indicate individual and combined aggregate gradations and aggregate source and characteristics.
         v. Submit design mixes for each type and class of concrete based on laboratory trial batch method or field experience.
         vi. If trial batch method is used, employ an independent testing agency acceptable to design-build team or architect for preparing and reporting proposed mix designs. Mix designs are to be prepared by a professional engineer licensed in the state; certificate signed and stamped by a PE shall be provided. Contractor-employed testing agency shall not be same firm as owner-employed testing agency.
         vii. Maintain records of concrete placement. Record date, location, quantity, air temperature, and test samples taken.
      2) Certificates:
         i. Provide certificate signed by authorized official of supplier with each load of concrete stating the following:
            a. Time truck left plant.
            b. Mix of concrete; identify with code number of mix design.
            c. Amount of water and cement in mix.
            d. Amount and type of admixtures.
            e. Amount of water added at project site.
            f. Time truck is unloaded at project site. Truck mixers without batch tickets will be rejected. Retain certificates at project site. Submit to owner for review upon request.
      3) See Submittal Register, Appendix II
   d. Warranties: See Submittal Register, Appendix II

3. **Field Control, Evaluation, and Commissioning**
   a. Testing agency
      1) The testing agency shall be designated by the owner. Ample time shall be allowed for preliminary tests as required prior to concreting operations.
      2) All testing agency personnel shall meet the requirements of ASTM E329.
      3) All testing agency personnel shall have the knowledge and ability to perform the necessary tests equivalent to the minimum guideline for Certification of Concrete Field Testing Technicians, Grade 1.
      4) Notify owner's testing laboratory a minimum of 48 hours prior to commencement of placing operations.

b. Inspect installation and verify work is complete and properly installed.

DIVISION 04 – MASONRY

Section 04 22 00 – Concrete Masonry Unit

1. **Overview:**
   a. Concrete masonry units, mortar and grout, steel reinforcing bars, masonry joint reinforcement, ties and anchors, embedded flashing, and miscellaneous masonry accessories for a complete installation.
2. **Performance Requirements:**
   a. Quality Assurance
      1) **Sample Panels**: build sample panels of a typical exterior and interior wall area.
      2) **Mock-ups**: Build mock-ups to verify selections made under sample submittals, to demonstrate aesthetic effects, and to set quality standards for materials and execution.
      3) Standards and certifications
   b. Sustainability
   c. Submittals
      1) **Mortar Color Selection**: Submit 2 copies of manufacturer's standard color selection for mortar color. Owner's review will be for color only. Compliance with all other requirements is the exclusive responsibility of the contractor.
      2) **Samples**: Submit two sets of masonry unit samples for approval, showing full range of variation in texture and color of the material. Masonry used in the work shall be within the approved limits.
      3) See Submittal Register, Appendix II
   d. Warranties: See Submittal Register, Appendix II
3. **Product Requirements:**
   a. Materials
      1) Split Face Hollow Concrete Masonry Units: ASTM C90 medium weight dark color aggregate with standard cement. Split face texture all exposed faces and ends.
         i. Provide open end units or "H" block units, for stacked bond pattern.
         ii. Provide bond beam units at horizontal reinforcing.
         iii. Provide open end units at vertical reinforcing.
      2) Split Face Solid Masonry Units: ASTM C56 Materials as specified for hollow concrete masonry units. Color to match hollow block units. Split face texture one side and exposed ends.
         i. Smooth Face Hollow Concrete Masonry Units: ASTM C90, medium weight smooth face, uniform gray color.
   b. Mortar and Grout Materials
      1) **Cement for Mortar and Grout**: Type I or Type II Portland cement conforming to ASTM C150. Type II Portland cement may be used only if it equals strength of Type I. All cement used (mortar and grout) shall be low alkali type (0.6% maximum).
      2) **Water**: Taken from a potable source.
      3) **Mortar Color Pigment**: Davis Colors, Solomon Colors, or approved equal. Color as selected by owner.
4. **Field Control, Evaluation, and Commissioning**
   a. **Source Limitations for Masonry Units**: Obtain exposed masonry units of a uniform texture and color, or a uniform blend within the ranges accepted for these characteristics, with all units from the same batch, through one source from a single manufacturer.
   b. **Cores**: Not required, except that if any mortar or grout specimens in structural elements fail to meet specified strengths, cores shall be taken as directed by owner.
   c. **Masonry Inspection**: Masonry work will be continuously inspected during laying by an inspector approved and paid by owner.

d. Retain the sample panel on the project for comparison purposes with the actual masonry work. If the sample panel is not part of the wall system, it shall be demolished and removed from the site after completion and acceptance for the project concrete masonry work.

e. **Special Inspection**: Coordinate all special inspections with owner's special inspection agency. 48 hours' notice shall be provided to special inspection agency.

f. Inspect installation and verify work is complete and properly installed.

DIVISION 05 – METALS

Not Used

DIVISION 06 – WOODS, PLASTICS, AND COMPOSITES

Not Used

Section 07 50 00 – Roofing and Waterproofing General Requirements

1. General:

This section establishes general requirements applicable to roofing and waterproofing systems for new construction, renovations, and repairs. The intent is to identify campus expectations and minimum performance criteria for roofing and waterproofing work. Coordinate roofing and waterproofing systems with Caltech Facilities Planning, Engineering & Architecture and Facilities Operations & Services.

2. Performance Requirements:

a. Roof Penetrations

Minimize roof penetrations and coordinate penetrations with all trades during design. Detail and install penetrations to maintain the integrity of the roofing system.

Engage the Carpenter Shop for review of roof-related work affecting existing or new roofing systems, including:

i. New penetrations
ii. Modifications to existing penetrations
iii. Repairs and patching

Provide temporary and permanent protection at roof penetrations to prevent water intrusion. Design and install penetrations in accordance with manufacturer recommendations and system requirements.

b. QA/QC Requirements

Develop a project-specific roofing and waterproofing QA/QC plan prior to the start of work. Review the QA/QC plan with Caltech Facilities Planning, Engineering & Architecture, Caltech PM, and Carpenter Shop.

QA/QC include the following:

i. Inspection hold points
ii. Testing requirements
iii. Documentation and reporting procedures

c. Hazardous Materials Testing

Evaluate existing roof assemblies for hazardous materials prior to disturbance. Testing should include roof layers, mastics, coatings, and other potentially affected materials.

Where hazardous materials are identified:

i. Complete abatement in accordance with applicable regulations.
ii. Obtain required clearance documentation prior to proceeding with work.

d. Weather Protection / Temporary Waterproofing

Develop an adverse weather protection plan prior to start of roofing work. Review the plan with Caltech Facilities Planning, Engineering & Architecture, Caltech PM, and Carpenter Shop. Maintain watertight conditions at all times during construction. Provide temporary waterproofing and protection for all exposed roof areas.

e. Project-Specific Requirements

This design guideline establishes minimum requirements and is not intended to replace project-specific design.

Evaluate roofing and waterproofing systems based on:

i. Building use and occupancy
ii. Existing conditions
iii. Sensitivity of spaces below

Review final system selection, detailing, and installation approach with Caltech Facilities Planning, Engineering & Architecture and Facilities Operations & Services.

Section 07 13 00 – Pre-Applied Sheet Membrane Waterproofing

1. Overview:

a. The work of this section includes, but is not limited to, blindside pre-applied sheet membrane waterproofing that forms a mechanical and chemical bond to concrete for the following applications:

1) **Horizontal Applications**: Membrane applied on prepared subbase prior to placement of concrete slabs.

2) **Vertical Applications**: Membrane applied against formwork or soil retention system prior to placement of concrete foundation walls.

3) Water stops for sealing concrete construction joints, pipe penetrations, and knockouts.

2. Performance Requirements:

a. Quality Assurance

1) Mock-up areas shall be used to determine required methods and tools to obtain the degree of backup preparation required by the membrane manufacturer. Prepare and clean a three (3) foot by three (3) foot area of each substrate material type.

2) Standards and Certifications

i. **Manufacturer's Qualifications**: Sheet membrane waterproofing system manufacturer shall demonstrate a minimum of fifteen (15) years' continuous, successful experience in production of waterproofing membranes.

ii. **Installer Qualifications**: Sheet membrane waterproofing system installation shall be performed by one contractor, approved by the waterproofing manufacturer, who shall have at least three (3) years' experience in work of the type required by this section.

3) American Society for Testing and Materials International (ASTM)

i. ASTM C836, Standard Specification for High Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane for Use with Separate Wearing Course

ii. ASTM D412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers — Tension

iii. ASTM D570, Standard Test Method for Water Absorption of Plastics

iv. ASTM D 903, Standard Test Method for Peel or Stripping Strength of Adhesive Bonds

v. ASTM D 1876, Standard Test Method for Peel Resistance of Adhesives (T-Peel Test)

vi. ASTM D1970, Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection

vii. ASTM D3767, Standard Practice for Rubber — Measurement of Dimensions

viii. ASTM D5385, Standard Test Method for Hydrostatic Pressure Resistance of Waterproofing Membranes

ix. ASTM E96, Standard Test Method for Water Vapor Transmission of Materials

x. ASTM E 154, Standard Test Methods for Water Vapor Retarders Used in Contact with Earth Under Concrete Slabs, on Walls, or as Ground Cover

4) **Pre-Installation Conference**: A pre-installation conference shall be held prior to commencement of field operations to establish procedures to maintain optimum working conditions, to coordinate this work with related and adjacent work, and to review special details.

5) Give a minimum of five (5) days' notice to the owner and manufacturer prior to commencing any work and notify both parties on a daily basis of any change in work schedule.

6) Contractor shall attend necessary job meetings and furnish competent and full-time supervision, experienced mechanics, and all materials, tools, and equipment necessary to complete, in an acceptable manner, the membrane installation in accordance with this specification.

7) **Materials**: Obtain primary sheet membrane waterproofing and all joint sealing and water stop materials of each type required from a single manufacturer. Manufacturer to provide waterproofing shop drawings.
8) **Backup Preparation**: Prepare the backup surfaces to accept the approved waterproofing system in the manner necessary to comply with all requirements of the membrane manufacturer and architect.
9) **Schedule Coordination**: Schedule work such that the membrane will not be left exposed to jobsite conditions for longer than recommended by the manufacturer. Manufacturer or manufacturer's representative to be on site during waterproofing installation a minimum of 3 times in addition to the preconstruction meeting, and additionally as may be required due to the complexity of the installation.

b. Submittals
1) Manufacturer's Product Data, installation instructions for waterproofing membrane system, and representative membrane samples for approval.
2) **LEED Submittals**: Provide LEED submittal information as required.
3) **Shop Drawings**: Manufacturer to provide shop drawings of the entire sub-grade waterproofing system showing locations and extent of all waterproofing materials, water stops, and accessories including details of substrate joints, penetrations, inside and outside corners, tie-ins with adjoining waterproofing, integration with air barrier system, and other termination conditions.
4) **Mock-up Panels**: Mock-up panels as specified herein shall be constructed by the contractor at locations selected by the architect, to test all products specified in this section and arrive at acceptable methods of installation.
5) See Submittal Register, Appendix II

c. Warranties
1) A single source manufacturer provided "watertight warranty" from date of substantial completion. Warranty to be negotiated and obtained by the applicator and manufacturer in writing and submitted as part of the material submittal package and included in the contract documents. Applicator is required to activate the warranty upon substantial completion.
2) Warranty includes all major waterproofing material components and covers the installation by manufacturer's approved contractor.
3) The waterproofing contractor must provide a 2-year workmanship warranty.
4) No amortization of the warranty is permitted.
5) No mandated inspections or additional material enhancements will be required during the warranty period to retain the warranty coverage.
6) All system components (drainage boards, termination bars, sealants, water stops, etc.) must be covered within the manufacturer's warranty.
7) See Submittal Register, Appendix II

3. Product Requirements:

a. Pre-Applied Sheet Waterproofing for Vertical Applications: Uniform, flexible, multilayered composite sheet membrane that forms a permanent bond with fresh concrete placed against it; complete with accessories and preformed shapes for an unbroken waterproofing assembly, with the following physical properties:
1) Physical Properties:
i. **Low-Temperature Flexibility**: Pass at minus 20 deg F (minus 29 deg C); ASTM D1970/D1970M.
ii. **Peel Adhesion to Concrete**: 5 lbf/in. (875 N/m) minimum; ASTM D
iii. 03, modified.
iv. **Lap Adhesion**: 5 lbf/in. (875 N/m) minimum; ASTM D1876, modified.
v. **Hydrostatic-Head Resistance**: 230 feet (70 m); ASTM D5385, modified.
vi. **Puncture Resistance**: 100 lbf (445 N) minimum; ASTM E154/E154M.
vii. **Water Vapor Permeance**: 0.1 perm (6 ng/(Pa·s·m^2)) maximum; ASTM E96/E96M, Water Method.
viii. **Ultimate Elongation**: 335% minimum; ASTM D412, modified.

b. Pre-Applied Sheet Waterproofing for Horizontal Applications: Uniform, flexible, multilayered composite sheet membrane that forms a permanent bond with fresh concrete placed against it; complete with accessories and preformed shapes for an unbroken waterproofing assembly, with the following physical properties:

1) Physical Properties:

i. L**ow-Temperature Flexibility**: Pass at minus 20 deg F (minus 29 deg C); ASTM D1970/D1970M.

ii. **Peel Adhesion to Concrete**: 5 lbf/in. (875 N/m) minimum; A

iii. TM D903, modified.

iv. **Lap Adhesion**: 5 lbf/in. (875 N/m) minimum; ASTM D1876, modified.

v. **Hydrostatic-Head Resistance**: 230 feet (70 m); ASTM D5385, modified.

vi. **Puncture Resistance**: 200 lbf (890 N) minimum; ASTM E154/E154M.

vii. **Water Vapor Permeance**: 0.1 perm (6 ng/(Pa·s·m^2)) maximum; ASTM E96/E96M, Water Method.

viii. **Ultimate Elongation**: 335% minimum; ASTM D412, modified.

c. All auxiliary materials as recommended by the waterproofing manufacturer for the intended use and compatible with the sheet waterproofing for a complete installation.

4. Installation Requirements:

a. The installer shall examine conditions of substrates and other conditions under which this work is to be performed and notify the contractor, in writing, of circumstances detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected.

b. Membrane Placement: Thickness of the sub-grade membrane shall be determined by the following factors and approved by the membrane manufacturer's technical representative and the architect:

1) Use on all horizontal surfaces and where rebar cages are placed next to vertical surfaces. Run vertical wall membrane to a height above the rebar concentration and marry to the horizontal membrane.

2) Use on all vertical surfaces where membrane will be pre-applied.

c. The substrate shall be of sufficient stability to prevent movement during the concrete placement. Substrates must be regular and smooth with no gaps or voids larger than 0.5 in. Acceptable substrates include concrete, permanent or removable formwork, plywood, fleece, rigid protection board, or drainage composite.

1) Horizontal Surfaces: The substrate must be free of loose aggregate and sharp protrusions. Avoid curved or rounded substrates. When installing over crushed stone or earth, ensure substrate is well compacted to prevent displacement of the substrate due to traffic or concrete placement. Substrate may be damp but standing water must be removed.

2) Vertical Surfaces: Use a suitable substrate such as permanent or temporary formwork, plywood, rigid protection board, or drainage composite to provide membrane support.

d. **General**: Strictly comply with installation instructions in manufacturer's published literature. Protect membrane in accordance with the manufacturer's published literature prior to backfilling operations.

5. Field Control, Evaluation, and Commissioning

a. Manufacturer's representative to inspect completed application and provide a written report that application complies with manufacturer's written instructions.

b. Perform work only when weather conditions as well as ambient and substrate temperatures are within the limits established by the manufacturer of the sheet membrane waterproofing system. Do not apply waterproofing in snow, rain, or mist.

c. Proceed with installation only when the substrate construction and preparation work is complete and is suitable to support sheet membrane waterproofing.

d. Deliver materials in manufacturer's original and unopened, labeled packages. Store and handle in strict compliance with manufacturer's instructions. Protect from damage from weather, excessive temperature, and construction operations. Remove and dispose of damaged material in accordance with applicable regulations.

e. Work shall be performed in accordance with the more stringent requirements of these specifications: the local building codes, OSHA, or other governmental authorities including federal, state, and local, having jurisdiction.

f. **Manufacturer's Technical Representatives**: Membrane manufacturer shall provide trained direct company personnel to attend necessary job meetings, perform periodic inspections as necessary, and conduct a final inspection upon successful completion of the installation.

g. Inspect installation and verify work is complete and properly installed.

Section 07 13 26 – Post Applied Self Adhering Sheet Membrane Waterproofing

1. Overview:

a. The work of this section includes, but is not limited to, self-adhering, post applied sheet membrane waterproofing consisting of a thick layer of polymeric waterproofing membrane on a heavy duty, cross-laminated polyethylene carrier film that forms a tenacious bond to concrete for the following applications:

1) **Horizontal Applications**: Membrane can be applied effectively for use as between-the-slab waterproofing on plaza decks, parking decks, and structural slabs.

2) **Vertical Applications**: waterproofing system provides an effective answer to properly waterproof foundations, vertical walls, and site retaining walls.

3) Water stops for sealing concrete construction joints, pipe penetrations, and knockouts.

2. Performance Requirements:

a. Quality Assurance

1) Mock-ups: Mock-up areas shall be used to determine required methods and tools to obtain degree of backup preparation required by the membrane manufacturer. Prepare and clean a three (3) foot by three (3) foot area of each substrate material type.

2) Standards and certifications

i. **Manufacturer's Qualifications**: Sheet membrane waterproofing system manufacturer shall demonstrate a minimum of ten (10) years' continuous, successful experience in production of waterproofing membranes.

ii. **Installer Qualifications**: Sheet membrane waterproofing system installation shall be performed by one contractor, approved by the waterproofing manufacturer, who shall have at least three (3) years' experience in work of the type required by this section.

iii. **American Society for Testing and Material International References**:

a) American Railway Engineering and Maintenance of Way Association (AREMA) Specification Chapter 29 — Waterproofing.

b) ASTM D146 — Standard Test Methods for Sampling and Testing Bitumen-Saturated Felts and Fabrics Used in Roofing and Waterproofing.

c) ASTM D412 — Standard Test Methods for Vulcanized Rubber and Thermoplastic Tension.

d) ASTM D570 — Standard Test Method for Water Absorption of Plastics.

e) ASTM D903 — Standard Test Method for Peel or Stripping Strength of Adhesive Bonds.

f) ASTM D1876 — Standard Test Method for Peel Resistance of Adhesives. (T-Peel Test).

g) ASTM D1970 — Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection.

h) ASTM E96 (Method B) — Standard Test Methods for Water Vapor Transmission of Materials.

i) ASTM E154 — Standard Test Methods for Water Vapor Retarders Used in Contact with Earth under Concrete Slabs, on Walls, or as Ground Cover.

iv. **Pre-Installation Conference**: A pre-installation conference shall be held prior to commencement of field operations to establish procedures to maintain optimum working conditions, to coordinate this work with related and adjacent work, and to review special details.
v. Give a minimum of three (3) days' notice to the owner and manufacturer prior to commencing any work and notify both parties on a daily basis of any change in work schedule.
vi. Contractor shall attend necessary job meetings and furnish competent and full-time supervision, experienced mechanics, and all materials, tools, and equipment necessary to complete, in an acceptable manner, the membrane installation in accordance with this specification.
vii. **Materials**: Obtain primary sheet membrane waterproofing and all joint sealing and water stop materials of each type required from a single manufacturer. Manufacturer to provide waterproofing shop drawings.
viii. **Backup Preparation**: The concrete contractor shall prepare the backup surfaces to accept the approved waterproofing system in the manner necessary to comply with all requirements of the membrane manufacturer and architect.
v. **Schedule Coordination**: Schedule work such that the membrane will not be left exposed to jobsite conditions for longer than that recommended by the manufacturer. Manufacturer or manufacturer's representative will make periodic site observations during installation of waterproofing system.

b. Submittals:
1) **Product Data**: Provide data for membrane, surface conditioner, flexible flashings, joint cover sheet, and joint and crack sealants.
2) **Shop Drawings**: Indicate special joint or termination conditions and conditions of interface with other materials.
3) **Certificate**: Certify that products meet or exceed specified requirements.
4) **Manufacturer's Installation Instructions**: Indicate special procedures.
5) **Warranty**: Submit manufacturer's warranty and ensure forms have been completed in Caltech's name and registered with manufacturer.
6) See Submittal Register, Appendix II

c. Warranties:
1) **Extended Warranty**: Provide written guarantee from waterproofing membrane manufacturer and furnish jointly written warranty to Caltech from waterproofing applicator and contractor, covering all membranes and other elements essential to be watertight.
2) Contractor shall correct defective work within a five-year period after date of substantial completion; and will remove and replace materials concealing waterproofing at no extra cost to Caltech.
3) Provide five-year manufacturer's warranty for waterproofing failing to resist penetration of water, except where such failures are the result of structural failures of building. Hairline cracking of concrete due to temperature change or shrinkage is not considered a structural failure
4) See Submittal Register, Appendix II

3. Product Requirements:

a. Self-Adhered Modified Bituminous Sheet Membrane:
1) **Thickness**: 60 mil(0.060 inch), minimum.
2) **Sheet Width**: 36-inch, minimum
3) **Tensile Strength**: 325 pounds per square inch, minimum, measured according to ASTM D412 Method A, using die C and at spindle-separation rate of 2 inches per minute.
4) **Elongation at Break**: 300%, minimum, measured according to ASTM D412.
5) **Water Vapor Permeance**: 0.05 perm, maximum, measured in accordance with ASTM E96/E96M.

6) **Low Temperature Flexibility**: Unaffected when tested according to ASTM D1970/D1970M at minus 20 degrees F over a 1-inch mandrel.
7) **Peel Strength**: 7 pounds per inch, minimum, when tested according to ASTM D903.
8) **Lap Adhesion Strength**: 5 pounds per inch, minimum, when tested according to ASTM D1876, modified for low temperature conditions.
9) **Puncture Resistance**: 50 pounds, minimum, measured in accordance with ASTM E154/E154M.
10) **Water Absorption**: 0.1% increase in weight, maximum, measured in accordance with ASTM D570, 24-hour immersion.
11) **Hydrostatic Resistance**: Resists the weight of 200 feet when tested according to ASTM D5385/D5385M.
12) **Adhesives, Sealants, Tapes, and Accessories**: As recommended by membrane manufacturer.

4. **Installation Requirements:** Install self-adhered modified bituminous sheets according to waterproofing manufacturer's written instructions.

5. **Field Control, Evaluation, and Commissioning**
   a. **Manufacturer's Field Service**: Engage a site representative qualified by waterproofing membrane manufacturer to inspect substrate conditions, surface preparation, membrane application, flashings, protection, and drainage components, and to furnish daily reports to architect.
   b. Inspect installation and verify work is complete and properly installed.

Section 07 14 16 – Cold Fluid–Applied Waterproofing

1. **Overview:**
   a. The work of this section includes, but is not limited to, low odor, low VOC cold fluid–applied waterproofing membranes. These membranes form a flexible, durable, and monolithic membrane and can be applied by spray, roller, brush, or squeegee. They products can be used in both new construction as well as restoration construction projects.
      1) **Horizontal Applications**: Cold fluid–applied waterproofing systems can be applied effectively for use as between-the slab waterproofing on plaza decks, parking decks, and structural slabs.
      2) **Vertical Applications**: Cold fluid-applied waterproofing systems provide an effective answer to properly waterproof foundations, vertical walls, and site retaining walls.
      3) **Planter Boxes**: Cold fluid–applied waterproofing systems' monolithic membranes provide excellent protection for many planter boxes and landscape features
      4) Water stops for sealing concrete construction joints, pipe penetrations, and knockouts.

2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
         i. Mock-up areas shall be used to determine required methods and tools to obtain degree of backup preparation required by the membrane manufacturer. Prepare and clean a three (3) foot by three (3) foot area of each substrate material type.
      2) Standards and certifications
         i. **Manufacturer's Qualifications**: Cold fluid–applied waterproofing system manufacturer shall demonstrate a minimum of ten (10) years' continuous, successful experience in production of waterproofing membranes.
         ii. **Installer Qualifications**: Cold fluid–applied waterproofing system installation shall be performed by one contractor, approved by the waterproofing manufacturer, who shall have at least three (3) years' experience in work of the type required by this section.
         iii. American Society for Testing and Material International References:

a. ASTM C1250 — Standard Test Method for Nonvolatile Content of Cold Liquid–Applied Elastomeric Waterproofing Membranes
b. ASTM C836 — Standard Specification for High Solids Content, Cold Liquid–Applied Elastomeric Waterproofing Membrane for Use with Separate Wearing Course
c. ASTM D412 — Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension
d. ASTM D2240 — Standard Test Method for Rubber Property—Durometer Hardness
e. ASTM D2369 — Standard Test Method for Volatile Content of Coatings
f. ASTM E96 — Standard Test Methods for Water Vapor Transmission of Materials
g. ASTM D1228 — Methods of Testing Asphalt Insulating Siding Surfaced with Mineral Granules
h. ASTM D1970-01 — Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection

3) **Pre-Installation Conference**: A pre-installation conference shall be held prior to commencement of field operations to establish procedures to maintain optimum working conditions, to coordinate this work with related and adjacent work, and to review special details.
4) Give a minimum of three (3) days' notice to the owner and manufacturer prior to commencing any work and notify both parties on a daily basis of any change in work schedule
5) Contractor shall attend necessary job meetings and furnish competent and full-time supervision, experienced mechanics, and all materials, tools, and equipment necessary to complete, in an acceptable manner, the membrane installation in accordance with this specification.
6) **Materials**: Obtain primary sheet membrane waterproofing and all joint sealing and water stop materials of each type required from a single manufacturer. Manufacturer to provide waterproofing shop drawings.
7) **Backup Preparation**: The concrete contractor shall prepare the backup surfaces to accept the approved waterproofing system in the manner necessary to comply with all requirements of the membrane manufacturer and architect.
8) **Schedule Coordination**: Schedule work such that the membrane will not be left exposed to jobsite conditions for longer than that recommended by the manufacturer. Manufacturer or manufacturer's representative will make periodic site observations during installation of waterproofing system.

b. Submittals

1) **Product Data**: Provide data for membrane, surface conditioner, flexible flashings, joint cover sheet, and joint and crack sealants.
2) **Shop Drawings**: Indicate special joint or termination conditions and conditions of interface with other materials.
3) **Certificate**: Certify that products meet or exceed specified requirements.
4) **Manufacturer's Installation Instructions**: Indicate special procedures.
5) **Warranty**: Submit manufacturer's warranty and ensure forms have been completed in Caltech's name and registered with manufacturer.
6) See Submittal Register, Appendix II.

c. Warranties

1) **Extended Warranty**: Provide written guarantee from waterproofing membrane manufacturer and furnish joint written warranty to the owner from waterproofing applicator and contractor, covering all membranes and other elements essential to be watertight.
2) Contractor shall correct defective work within a five-year period after date of substantial completion and shall remove and replace materials concealing waterproofing at no extra cost to Caltech.
3) Provide five-year manufacturer's warranty for waterproofing failing to resist penetration of water, except where such failures are the result of structural failures of building. Hairline cracking of concrete due to temperature change or shrinkage is not considered a structural failure.
4) See Submittal Register, Appendix II.

3. **Product Requirements:**
   a. **Cold Fluid–Applied Waterproofing Membrane**: Waterproofing membrane shall have the following properties as determined by laboratory testing:
      1) **Waterproofing Membrane**: single-component, polymer-modified, cold-applied, liquid waterproofing membrane
         i. **Color**: Black
         ii. **Solids**: 70%
         iii. **Total Cure Time**: 16–24 hours
         iv. **Shore "00" Hardness, ASTM C836**: Passes
         v. **Adhesion to Concrete, ASTM C836**: Exceeds
         vi. **Low Temperature Flex and Crack Bridging, ASTM C836**: Passes
         vii. **Stability, ASTM C836**: Exceeds
         viii. **Elongation, ASTM D412**: 1500%
         ix. **Water Absorption, ASTM D1970**: 0.7%
         x. **Water Vapor Transmission, ASTM E96 (Method B):** 0.03 perms
         xi. **VOC Content**: 50g/l max
      2) **Waterproofing Membrane**: single-component, cold-applied, solvent-free, non-shrink, liquid waterproofing membrane.
         i. **Solids Content by Weight, ASTM C1250:** 98%
         ii. **Tensile Strength, ASTM D412**: 100 psi
         iii. **Elongation at Break, ASTM D412**: 425%
         iv. **Water Vapor Transmission, ASTM E96 (Method BW):** 0.1 perms
         v. **Shore 00 Hardness, ASTM D2240**: 57
         vi. **VOC, ASTM D2369**: 50 g/L max
         vii. Certified by manufacturer for vertical or horizontal use.
      3) **Waterproofing Membrane**: Single-component, cold applied water curable waterproofing membrane system for vertical or horizontal surfaces.
         i. **Hardness, ASTM D2240**: >30 Shore A
         ii. **Elongation, ASTM D412**: 425% minimum
         iii. **Tensile Strength, ASTM D 412**: 300 psi minimum
         iv. **Tear Resistance, Die C. ASTM D624**: 70 pli minimum
         v. **Solids Content by Weight, ASTM2369**: 90% minimum
         vi. **VOC Content, ASTM 2369**: 50 g/l maximum
      4) **Cold Fluid–Applied Waterproofing**: Polyurethane-methacrylate (PUMA)—based membrane. A two-component methacrylate-based (PUMA) liquid membrane
         i. **VOC Content**: 50 g/L, all grades.
         ii. **Elongation ASTM D-638**: 250% minimum
         iii. **Crack Bridging, ASTM C1305**: Pass.
         iv. **Tensile Strength D-638 at 75 degrees F**: 425 psi minimum
         v. **Hardness, ASTM C2240**: 90 minimum
         vi. **Tear Resistance, ASTM D624**: 100 psi minimum
         vii. System recommended for horizontal use

4. **Installation Requirements:** Install waterproofing membrane according to waterproofing manufacturer's written instructions.

5. **Field Control, Evaluation, and Commissioning:**

a. Manufacturer's representative to inspect completed waterproofing installation before covering with other construction and provide written report that installation complies with manufacturer's written instructions.
b. Inspect installation and verify work is complete and properly installed.

Section 07 18 00 – Traffic Coating

1. **Overview:**
   a. Section includes fluid-applied heavy-duty vehicular traffic coating.

2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
   b. Sustainability
   c. Submittals
      1) See Submittal Register, Appendix II
   d. Warranties
      1) Contractor shall submit warranty, signed by manufacturer, agreeing to repair or replace traffic coating that fails in materials or workmanship, including all components of traffic coating system, for five years from date of substantial completion.
      2) See Submittal Register, Appendix II

3. **Product Requirements:**
   a. **Traffic Coatings:** Manufacturer's standard, traffic-bearing, seamless, high-solids-content, cold liquid-applied, elastomeric, waterproofing membrane system with integral wearing surface for exterior pedestrian and vehicular traffic according to ASTM C 957. Include sealants, sheet flashing, adhesive, reinforcing strip, and pavement markings as required for a complete system.

4. **Installation Requirements:** Install per manufacturer's recommendations.

5. **Field Control, Evaluation, and Commissioning:**
   a. Manufacturer's representative to inspect completed application and provide a written report that application complies with manufacturer's written instructions.
   b. Inspect installation and verify work is complete and properly installed.

Section 07 26 16 – Below-Grade Vapor Retarders

1. **Overview:** Slab-on-grade supplementary components

2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
   b. Sustainability
   c. Submittals
      1) See Submittal Register, Appendix II
   d. Warranties
      1) Minimum 10–year warranty to be provided.
      2) See Submittal Register, Appendix II

3. **Product Requirements:**
   a. **Vapor Retarder**: Provide minimum 15–mil-thick vapor retarder, complying with ASTM E 1745, minimum Class B, directly under all concrete slabs on grade.
4. **Installation Requirements:**
   a. Vapor retarder shall connect to air barrier and/or waterproofing membrane(s) to form a continuous seal around the building. Do not place granular fill between vapor retarder and concrete slab.
5. **Field Control, Evaluation, and Commissioning:**
   a. Inspect installation and verify work is complete and properly installed.

Section 07 52 00 – Modified Bituminous Membrane Roofing

1. **Overview:**
   a. **New Construction or Full Roof Replacement with Moderate to High Volume Maintenance Foot Traffic.**
      1) Adhered Modified Asphalt Roofing over Adhered or Mechanically Attached Roof Boards
         a) APP or SBS Modified System
2. **Performance Requirements:**
   a. Roofing system must resist wind uplifts and water transmission for a minimum of 30 years without requiring significant enhancement or upgrade (coating, etc.).
   b. Roof slopes must be a minimum ¼–inch per foot sloped to drains when measured along the major roof slopes.
   c. Standing water must not remain on the roof for more than 72 hours after a rain event.
   d. Insulation and cover boards must be installed to resist 90 lbs/ft^2 wind uplift in the central zone of the roof and enhanced to resist higher wind loads in the perimeter and corner zones of the roof in accordance with FM standards.
   e. Quality Assurance
      1) Mock-ups
         a) Mock-Up: Perform mock-up prior to commencement of work. Include adhesion/fastener pull test as part of the mock-up under the oversite of the manufacturer's representative.
         b) Hold a preconstruction meeting with the manufacturer's technical representative and all other trades interfacing with the roofing work at least one week prior to starting roofing work.
         c) Walk the roof immediately after the preconstruction meeting to establish installation standards and identify any limitations of problematic conditions.
         d) Roofing contractor must be approved by the roofing manufacturer.
      2) Standards and certifications
         a) ASTM D6223, Type II, Grade G
         b) CA Title 24 Compliant Cool Roof System
         c) UL Class A Fire Rated Roofing System
         d) Insulation boards shall comply with ASTM C1289 Type II Class 2 Grade 3. Insulation to be UL Certified Green Guard Gold (GGG) for air quality.
   f. Submittals
      1) LEED documentation
      2) UL Certified insulation Green Guard Gold (GGG) for air quality.
   g. Submittals
      1) Contractor must provide a complete set of shop drawings stamped approved by the roofing system manufacturer.
      2) Independently recognized longevity documentation
      3) Attachment plans/layout demonstrating wind uplift resistance
      4) 30 NDL warranty sample must include detailed maintenance requirement
      5) UL GGG Certification for Insulation
      6) See Submittal Register, Appendix II

h. Warranties

1) A single source manufacturer-provided "no dollar limit watertight" warranty for the minimum period of 30 years from date of substantial completion. Warranty to be negotiated and obtained by the applicator and manufacturer in writing and submitted as part of the material submittal package and included in the contract documents. Applicator is required to activate the warranty upon substantial completion.

2) Warranty includes all major roofing material components and covers the installation by manufacturer's approved contractor.

3) The roofing contractor must provide a 2–year workmanship warranty

4) No amortization of the warranty is permitted.

5) No mandated inspections or additional material enhancements will be required during the warranty period to retain the warranty coverage.

6) All system components (cover boards, insulation, adhesives, etc.) must be covered within the manufacturer's warranty.

7) See Submittal Register, Appendix II

3. Product Requirements:

a. All system components are to be installed by the manufacturer's approved roofing contractors.

b. Roofing system must have a real-time track record of longevity in excess of the 30 years to match the warranty; accelerated predictive testing is not sufficient.

c. Roofing system must have an independently verified longevity in excess of 30 years.

d. Roofing membrane must be directly manufactured by the provider for a minimum of the warranty period. Third party manufactured systems and roofing reseller provided systems are prohibited.

e. Meets and exceeds requirements of ASTM D6223, Type II, Grade G

f. **Roof Membrane**: APP or SBS modified, minimum two ply heavily reinforced (at least 5 layers of reinforcement) system

g. **Membrane Thickness**: Minimum thickness 320 mils of membrane exclusive of adhesive thickness.

h. **Membrane Adhesive**: Cold applied, Low VOC, minimum 78% solids, modified asphalt adhesive.

i. **Cant Strips**: Provide manufacturers modified asphalt cant strips.

j. Wood fiber, perlite and vermiculite components are prohibited.

k. **Roof Boards**: 4 feet x 4 feet ½–inch thickness pre-primed EONIC (low moisture absorption) gypsum cover boards

l. **Insulation**: Mechanically attached or adhered 4 feet x 4 feet rigid polyisocyanurate roof insulation.

m. Provide manufacturer furnished tapered insulation to ensure a minimum ¼ inch per foot slope to drains when measured along the major roof slopes.

n. For all repairs, testing for compatibility of products is required. Coordinate with Caltech Roofing Shop. Recommended roofing repair products:

1) Castagra Ecodur One — for full coatings of existing roofs.

2) Castagra Ecodur Plus — for localized repairs.

4. Installation Requirements:

a. System selection and site procedures must be chosen to minimize dust, odors, and noise during installation.

b. System membrane layers must be applied in multiple 30 mils thickness layers of cold applied, Low VOC, minimum 78% solids, modified asphalt adhesive.

c. Membrane system laps shall be installed in accordance with manufacturer's requirements. Use of open flames is prohibited on campus.

d. New roofing system must be sealed every night to prevent accidental moisture ingress during construction.

5. Field Control, Evaluation, and Commissioning:

a. Manufacturer's technical field inspector must inspect the roof at start-up, two interim inspections, and a final inspection for warranty. Reports to be provided to the AOR within 10 business days of inspection.

b. Inspect installation and verify work is complete and properly installed.

Section 07 54 19 – Polyvinyl Chloride Roofing

1. **Overview:**
   a. **New Construction, Roof Replacement, and Existing Roof Overlay with low volume maintenance foot traffic.**
      1) Single ply roofing over existing roof or adhered or mechanically attached roof boards
         a) Adhered PVC single ply system over mechanically attached cover boards and insulation over plywood or metal deck.
         b) Adhered PVC single ply system over adhered cover boards and insulation over concrete deck.
         c) Adhered felt backed PVC single ply system over an existing mineral cap sheet asphalt roof.
         d) Adhered PVC single ply system over adhered cover boards and insulation over an existing asphalt roof.

2. **Performance Requirements:**
   a. Provide a manufacturer furnished complete roof system installed by manufacturer's approved roofing contractors.
   b. All system components are to be installed by the manufacturer's approved roofing contractors.
   c. Roof system must prevent water ingress into the building.
   d. Roof system must have a longevity greater than 30 years.
   e. Roof system must resist wind uplifts of 90lbs/ft2 in the central zone of the roof with enhanced attachment at corners and perimeter zones in accordance with FM standards.
   f. PVC roof system must remain weldable allowing modifications post installation, for the entire life of the membrane, and be able to demonstrate examples of modifications/welds to membranes older than 20 years.
   g. Roof slopes must be a minimum ¼ inch per foot slope to drains when measured along the major roof slopes. Special allowances will be made for existing roof overlays where slope enhancement is impractical, or curb height limitations prevent slope enhancement without any negative effect on the roof warranty.
   h. Quality Assurance
      1) Mock-ups
         a) Mock-up: Perform mock-up prior to commencement of work. Include adhesion/fastener pull test as part of the mock-up under the oversite of the manufacturer's representative.
         b) Hold a preconstruction meeting with the manufacturer's technical representative and all other trades interfacing with the roofing work at least one week prior to starting roofing work.
         c) Walk the roof immediately after the preconstruction meeting to establish installation standards and identify any limitations of problematic conditions.
         d) Roofing contractor must be approved by the roofing manufacturer.
      2) Standards and certifications
         a) Platinum level NSF/ANSI 347
         b) CA Title 24 Compliant Cool Roof
         c) UL Class A Fire Rated System
         d) Roof Membrane to be manufactured to ASTM 4434 Type II Grade 1 standard
         e) Insulation boards are to be manufactured to ASTM 1289 Type II Class 2 Grade 3. Insulation to be UL Certified Green Guard Gold (GGG) for air quality.

   i. Sustainability
      1) Platinum level NSF/ANSI 347 certified
      2) Roofing system must have a minimum post-consumer recycled content of 1%.
      3) Roofing manufacturer must provide LEED documentation.
      4) Insulation must be UL Certified Insulation Green Guard Gold (GGG) for air quality.

   j. Submittals
      1) Contractor must provide a complete set of shop drawings stamped "Approved" by the roofing system manufacturer.
      2) Independently recognized longevity documentation
      3) Attachment plans/layout demonstrating wind uplift resistance
      4) 30 NDL warranty sample must including detailed maintenance requirement.
      5) UL GGG certification for insulation

6) Copy of the manufacturer's Underwriters Laboratories Environment (ULE) validation of specified post-consumer recycled content.
7) Copy of manufacturer's platinum level NSF/ANSI 347 Sustainability Assessment certificate.
8) See Submittal Register, Appendix II.

k. Warranties
1) A single source manufacturer-provided "no dollar limit watertight" warranty for the minimum period of 30 years from date of substantial completion. Warranty to be negotiated and obtained by the applicator and manufacturer in writing and submitted as part of the material submittal package and included in the contract documents. Applicator is required to activate the warranty upon substantial completion.
2) The roofing contractor must provide a 2-year workmanship warranty.
3) Includes all major roofing material components and covers the installation by manufacturer's approved contractor.
4) No amortization of the warranty or mandated inspections or additional material enhancements will be required during the warranty period to retain the warranty coverage.
5) All system components (cover boards, insulation, adhesives, etc.) must be covered within the manufacturer's warranty.
6) See Submittal Register, Appendix II.

3. Product Requirements:

a. Roofing system must have a real time track record of longevity in excess of the 30 years to match the warranty; accelerated predictive testing is not sufficient.
b. Roofing system must have an independently verified longevity in excess of 30 years.
c. Roofing membrane system shall be manufactured and warranted directly by the membrane manufacturer for a minimum 30-year warranty period. Third-party manufactured systems and roofing reseller provided systems are prohibited.
d. **Roof Membrane**: PVC, ASTM 4434 Type II Grade 1 Glass Fiber Reinforced System
e. **Membrane Thickness**: Minimum 80 mils thickness of PVC membrane exclusive of applied fleece backing or adhesive thickness.
f. Self-adhered PVC membrane is to be installed when installing roofing over cover boards.
g. Polyester felt backed membranes used for directly applied mineral cap sheet roof overlays must have a minimum 9 oz/square yard weight fleece.
h. **Dimensional stability**: PVC roof membrane must remain stable after installation. Results when tested to ASTM 1204 linear dimensional change must be no more than +/- 0.01%.
i. **Water absorption**: Product must be tested to ASTM D-570; the "M" modified test employed by some manufactures unable to meet the original D-570 standard will not be acceptable.
j. **Membrane Adhesive**: Cold applied, water based, or two component polyurethane based Low VOC adhesive. High odor or hot applied bituminous adhesives are prohibited.
k. **Roof Boards**: 4 feet x 8 feet ¼ inch thickness pre-primed EONIC (low moisture absorption) gypsum cover boards
l. **Insulation**: UL GGG certified mechanically attached or adhered rigid polyisocyanurate roof insulation with inorganic glass fiber facers, manufactured to ASTM 1289 Type II Class 2 Grade 3

4. Installation Requirements:

a. System selection and site procedures must be chosen to minimize dust, odors, and noise during installation.
b. Membrane system laps must be hot air welded (use of flames or solvent welding is prohibited on the campus).
c. New roofing system must be sealed every night to prevent accidental moisture ingress during construction.

5. Field Control, Evaluation, and Commissioning:

a. Manufacturer's technical field inspector must inspect the roof at start-up, two interim inspections, and a final inspection for warranty. Reports to be provided to the AOR within 10 business days of inspection.
b. Inspect installation and verify work is complete and properly installed.

Section 07 56 00 – Fluid Applied Roofing

1. **Overview:**
   a. **New Construction, Roof Replacement, Roof Overlay or Accessory System.**
      1) Single component polyurethane moisture triggered, fully reinforced, liquid applied membrane (LAM) roofing over adhered or mechanically attached roof boards or over existing substrates.

2. **Performance Requirements:**
   a. Provide a manufacturer-furnished complete roof system installed by manufacturer's approved roofing contractors.
   b. All system components are to be installed by the manufacturer's approved roofing contractors.
   c. Roofing system must have an NDL full system warranty of 25 years without requiring significant enhancement or upgrade (re-coating, etc.). The roofing system warranty must be eligible for extension at the end of the 25-year warranty term for an additional 10 years with the application of another 30 mils topcoat.
   d. The cold fluid applied polyurethane waterproofing system is to perform as a continuous barrier against liquid water and to flash or discharge to the exterior incidental water.
   e. Membrane system shall accommodate movements of building materials as required with manufacturer's accessory sealant materials at such locations such as: changes in substrate, perimeter conditions, and penetrations.
   f. Roof slopes must be a minimum ¼ inch per foot slope to drains when measured along the major roof slopes. Exceptions can be made for roof overlay systems at the discretion of the manufacturer.
   g. Roof system must resist wind uplifts of 90lbs/ft2 in the central zone of the roof with enhanced attachment at corners and perimeter zones in accordance with FM standards
   h. Roof system must have a strong resistance to a wide range of reagents, including paraffin, gasoline, fuel oil, white spirit, acid rain, detergents, and moderate solutions of acids and alkalis.
   i. Quality Assurance
      1) **Mock-ups**
         a) **Mock-up**: Perform mock-up prior to commencement of work. Include adhesion/fastener pull test as part of the mock-up under the oversite of the manufacturer's representative.
         b) Hold a preconstruction meeting with the manufacturer's technical representative and all other trades interfacing with the roofing work at least one week prior to starting roofing work.
         c) Walk the roof immediately after the preconstruction meeting to establish installation standards and identify any limitations or problematic conditions.
         d) Roofing contractor must be approved by the roofing manufacturer prior to bid.
      2) **Standards and Certifications**
         a) **FM Global Compliance**: Certification that the roofing/waterproofing membrane meets FM Global Approval Standard 4470 for Class I roof covers, on non-combustible substrates, with up to a Class 1-990 wind uplift rating, a hail rating of SH, and is ASTM E-108-00 Class A approved at a slope of 1 in 12.
         b) **VOC Certification**: Manufacturer's certification that all roofing/waterproofing system products meet current VOC regulations as established by the state in which they are being installed; and stating total VOC content, in grams per liter, for all system components (i.e., primers, adhesives, coatings, etc.).
         c) **Meets ASTM D7311-07**: Standard Specification for Liquid-Applied, Single-Pack, Moisture-Triggered, Aliphatic Polyurethane Roofing Membrane.
         d) CA Title 24 Compliant Cool Roof
         e) Class A Fire Rated System
         f) Insulation boards are to be manufactured to ASTM 1289 Type II Class 2 Grade 3. Insulation to be UL Certified Green Guard Gold (GGG) for air quality.
   j. Sustainability
      1) LEED documentation

   k. Submittals
      1) Contractor must provide a complete set of shop drawings stamped "Approved" by the roofing system manufacturer.
      2) Attachment plans/layout demonstrating wind uplift resistance.
      3) 25 NDL warranty sample must include any maintenance requirement.

4) List of minimum 3 reference projects with a longevity exceeding 25 years.
5) UL GGG Certification for Insulation
6) See Submittal Register, Appendix II

l. Warranties
1) A single source manufacturer-provided "no dollar limit watertight" warranty for the minimum period of 25 years from date of substantial completion. Warranty to be negotiated and obtained by the applicator and manufacturer in writing and submitted as part of the material submittal package and included in the contract documents. Applicator is required to activate the warranty upon substantial completion.
2) Warranty includes all major roofing material components and covers the installation by manufacturer's approved contractor.
3) The roofing contractor must provide a 2-year workmanship warranty.
4) No amortization of the warranty is permitted.
5) No mandated inspections or additional material enhancements will be required during the warranty period to retain the warranty coverage.
6) All system components (cover boards, insulation, adhesives, etc.) must be covered within the manufacturer's warranty.
7) See Submittal Register, Appendix II.

3. Product Requirements:

a. Provide manufacturer-furnished, approved contractor installed system. Membrane manufacturer must provide all components of the system.
b. **Materials Compatibility**: All materials included in the roofing/waterproofing assembly, as well as associated materials adhered to/applied beneath the roofing/waterproofing membrane, shall have been tested and verified to be compatible. Include written testing documentation and test reports if requested by architect.
c. Roofing system must have a real-time track record of longevity in excess of the 25 years to match the warranty; accelerated predictive testing is not sufficient.
d. Roofing membrane system shall be manufactured and warrantied directly by the membrane manufacturer for a minimum 30-year warranty period. Third-party manufactured systems and roofing reseller provided systems are prohibited.
e. **Meets and exceeds requirements of ASTM D7311-07**: Standard Specification for Liquid-Applied, Single-Pack, Moisture-Triggered, Aliphatic Polyurethane Roofing Membrane.
f. **Roof Membrane**: Provide a glass fiber mat reinforced roofing membrane applied over a two-component epoxy primer over a manufacturer-approved substrate.
g. **Membrane Thickness**: Minimum dry film thickness 84 mils of membrane exclusive of primer layer(s).
h. **Roof Boards**: 4 feet x 8 feet ¼– or ½–inch thickness pre-primed EONIC (low moisture absorption) gypsum cover boards.
i. **Insulation**: Mechanically attached or adhered 4 feet x 4 feet rigid polyisocyanurate roof insulation.
j. Provide manufacturer furnished tapered insulation to ensure a minimum ¼ inch per foot slope to drains when measured along the major roof slopes.
k. For all repairs, testing for compatibility of products is required. Coordinate with Caltech Roofing Shop. Recommended roofing repair products:
1) Castagra Ecodur One – for full coatings of existing roofs.
2) Castagra Ecodur Plus – for localized repairs.

4. Installation Requirements:

a. System selection and site procedures must be chosen to minimize dust, odors, and noise during installation.
b. **System membrane layers must be applied as follows**: Epoxy primer is applied at 200–250 ft^2/gallon. Membrane base coat is applied at 50 mils and a glass fiber reinforcement is embedded in the wet membrane. Over the cured base coat, the topcoat of the same resin is applied in two passes of 23 mils each. If a slip resistant pathway or balcony type wearing surface is required, this must be applied in addition to the layers described above.
c. New roofing system must be sealed every night to prevent accidental moisture ingress during construction.

5. **Field Control, Evaluation, and Commissioning:**
   - **a.** Manufacturers technical field inspector must inspect the roof at start-up, two interim inspections, and a final inspection for warranty. Reports to be provided to the AOR within 10 business days of inspection.
   - **b.** Final Inspection: Manufacturer's representative shall provide to the architect a comprehensive site visit report after the completion of the roofing/waterproofing system.
   - **c.** Inspect installation and verify work is complete and properly installed.

Section 07 57 13 – Sprayed Polyurethane Foam Roofing

1. **Overview:**
   - **a. Exterior Ducting**
     - **1)** Furnish all labor, materials, tools, and equipment necessary for the application of a sprayed polyurethane foam (SPF) insulation system of ducting, including accessory items, subject to the general provisions of the contract.
   - **b.** Related work specified elsewhere:
     - **1)** Rough Carpentry
     - **2)** Insulation
     - **3)** Thermal Barrier
     - **4)** Vapor Retarder
     - **5)** Mechanical Division
   - **c. Sequence and scheduling**: In new construction projects the SPF is installed when the preparation of the ducting is in place and in coordination with other building trades.
   - **d.** Safety requirements
     - **1)** See API Bulletin MDI-Based Polyurethane Foam Systems: Guidelines for Safe Handling and Disposal, Stock Number AX-119.
     - **2)** Refer to appropriate material safety data sheets (SDS) for additional safety information.
     - **3)** Before starting to apply spray polyurethane foam or coating, all HVAC equipment on the roof must be turned off. These units and any other potential sources of air entry into the building must be sealed.
     - **4)** Proper disposal of waste materials and containers must be done in compliance with the manufacturer's guidelines and/or federal, state, and local regulation agencies.
     - **5)** For protection against exposure to higher levels of MDI (greater than 1 ppm) or for entry into confined spaces, workers must wear either a self-contained breathing apparatus, with full face piece, operated in a pressure-demand or other positive-pressure mode, or a combination respirator, including a type C air-supplied respirator, with full face piece, operated in a pressure-demand or other positive-pressure mode, and an auxiliary self-contained breathing apparatus, operated in a pressure-demand or other positive-pressure mode. Personal protective clothing shall be worn. This includes the wearing of the appropriate protective clothing, including eye protection (face shield or chemical worker's goggles), gloves and coveralls. This is essential to preventing skin exposure and is strongly recommended for most individuals who work with PMDI.

2. **Performance Requirements:**
   - **a.** Quality Assurance
     - **1)** Mock-ups
     - **2)** Standards and certifications
   - **b.** Sustainability
   - **c.** Submittals
     - **1)** Manufacturer's published data sheets or letter of certification that their products comply with the materials specified. This is to include SPF and, if required, coatings, primers, thermal barriers, and vapor retarders.
     - **2)** Shop drawings on sheet metal, accessories, or other fabricated items, if required.
     - **3)** Manufacturer's application or installation instructions.
     - **4)** Contractor/applicator certification from SPF supplier and/or coating and thermal barrier manufacturers and references.

5) Safety and handling instructions for storage, handling, and use of the materials to include material safety data sheets (SDS).

6) Field quality control procedures to be utilized by the contractor/applicator to insure proper preparation and installation of SPF, coating, and thermal barriers, detail work, and follow-up inspection.

7) See Submittal Register, Appendix II.

d. Warranties

1) See Submittal Register, Appendix II.

3. Product Requirements:

a. Polyurethane Foam: Shall be two-component made by combining an isocyanate (A) component with a polyol resin (B) component and shall possess the following physical characteristics.

b. Polyurethane Foam Primers: Primers used shall be as recommended by the manufacturer of the SPF materials specified.

c. Fire Safety Requirements: See API Publication MDI-Based Polyurethane Foam Systems: Guidelines for Safe Handling and Disposal, Stock Number AX- 119.

d. Exterior polyurethane foam

PROPERTIES	ASTM TEST	VALUE	UNITS
Density (sprayed-in-place)	D–1622	40 – 50 (2.5 – 3.0)	kg/m^3 (lbs/ft^3)
Compressive Strength	D–1621	280 (40) (Minimum)	kPa (lb/in^2)
Closed Cell content	D–2856	90% (Minimum)	% Value
R-Value		1.1 (6.2) Aged	K • m^2/W (◦F • ft^2 • hr/BTU)
Flammability *	E–84	< 75	
Smoke *	E–84	< 450	

* This standard is used solely to measure and describe properties of products in response to heat and flame under controlled laboratory conditions. This numerical flame spread rating is not intended to reflect hazards present by this or any other material under actual fire conditions.

e. Protective coating system

1) The elastomeric coating system may be one or more of the following types:

i. Acrylic

ii. Silicone

iii. Polyurethane elastomer

2) Physical Properties: The elastomeric coating system shall comply with the following minimum physical property requirements.

General: It is recommended that the coating system be elastomeric in nature (at least 100% elongation). Within these generic-coating types are both vapor retardant and breathable systems.

PROTECTIVE COATING SYSTEM

PROPERTIES	ASTM TEST	Value
Tensile Strength	ASTM D412	200 psi minimum
Elongation	ASTM D412	100% minimum
Hardness Shore A	ASTM D2240	40–70
Tear Resistance	ASTM D624	25 lbf/in minimum
Light Exposure and Weathering	ASTM G151 / G154	No cracking, checking, blistering, or peeling

PROPERTIES	ASTM TEST	Value
Tensile Strength	ASTM D412	200 psi minimum
Elongation	ASTM D412	100% minimum
Hardness Shore A	ASTM D2240	40–70
Moisture Vapor Transmission	ASTM E96 Procedure E	Manufacturer's standard published value
Chemical Resistance	ASTM D1308	No deleterious effects

f. System requirements

1) Polyurethane foam insulation shall be spray-applied to a minimum thickness of 2.5 inches (plus or minus ¼ inch) to equal an average R-7.

2) Coating shall be applied in a minimum of three (3) separate coats. Acrylic coating to be 60% solids.

i. The base coat shall be applied at a rate of 1 gallon per 100 square feet.

ii. The mid coat shall be applied at a rate of 1¼ gallons per 100 square feet.

iii. The topcoat shall be applied at a rate of 1¼ gallons per 100 square feet, yielding a total system thickness for both coats of 28–30 total dry mils.

iv. During the final topcoat application, size #11 granules will be embedded into the wet topcoat material at a rate of 40 pounds per 100 square feet.

g. Related products

1) 15–Minute Rated Thermal Barriers

i. Sprayed-in-place cementitious

ii. Sprayed-in-place fiber

iii. Minimum 13 mm (½–inch) gypsum board

2) **Vapor Retarder**: That which is rated at or less than 3 ng/m * s Pa (0.05 perm) ASTM E-96, Method E.

i. Modified asphalt

ii. Butyl rubber

iii. Polyethylene film

3) **Substrate Primers (if required):** The primer to be applied must be specifically selected for the given substrate to be primed and must be compatible with the SPF.

4. Installation Requirements

a. Application of products: The products for the insulation systems must be applied within the manufacturer's guidelines for temperature, humidity, and other atmospheric conditions. In addition, they must be sequenced so as to take into consideration substrate preparation, proper cure times, and inter-coat adhesion.

1) Environmental conditions

i. Do not apply the SPF below the temperature and/or above the humidity specified by the manufacturer for ambient air or substrate. If foam is being applied to a metal building's exterior, do not apply during inclement weather.

ii. Do not apply protective coatings when there is ice, frost, surface moisture, or dampness present on the surface to be coated. Prior to applying the coatings, check the polyurethane foam to ensure the surface is dry. Apply protective coatings in accordance with the coating manufacturer's application instructions.

b. Substrate consideration and preparation: Surface preparation shall be as outlined below:

1) **Primed**: If the primed metal surface is free of loose scale, rust, and weathered or chalking paint it can be cleaned using pressure washing, steam cleaning, solvent cleaning, vacuum equipment, or hand or power tools to remove loose dirt, grease, oil, or other contaminants.
2) **Galvanized and stainless steel**: When required, clean surface as recommended by the primer manufacturer.
3) **Unpainted Steel**: Clean as recommended by primer manufacturer in order to prepare the steel surface for the primer.

c. **Primer application**: When required, the primer shall be applied to the properly prepared substrate and allowed to cure according to the manufacturer's guidelines.

d. **Spray polyurethane foam application**

1) The spray polyurethane foam components (A) and (B) shall be processed in accordance with the manufacturer's instructions.
2) The polyurethane foam shall be sprayed per the manufacturer's guidelines for temperature and other atmospheric conditions. Take precautions to protect surroundings from overspray.
3) The polyurethane foam shall be sprayed in minimum 13 mm (½ inch) thick passes (lifts) with the overall thickness not to exceed the ICC-ES evaluation recommendation for the exact product being applied. The full thickness of SPF to be applied within any given area shall be completed in one day.
4) The final sprayed polyurethane foam surface shall be "smooth, orange peel, coarse orange peel, or verge of popcorn." Polyurethane foam surfaces termed "popcorn" or "tree bark" are not acceptable and shall be corrected. See SPFA publication "Spray Polyurethane Foam Systems for New and Remedial Roofing" for foam texture photographs. Stock Number AY-104.
5) Any damage or defects to the polyurethane foam shall be repaired prior to applying protective coatings, vapor retarders, or thermal barriers.
6) The polyurethane foam surface shall be free of contaminants that will impair adhesion of the protective coatings, vapor retarders, or thermal barriers.

e. **Protective coating application**

1) Inspection: Prior to the application of the protective coatings, the polyurethane foam shall be inspected to ensure the surface is properly prepared and suitable for coating application.
2) The coating application shall not proceed during inclement weather. The applicator shall apply the protective coating within the temperature and humidity ranges specified by the manufacturer for ambient air and substrate. Wind barriers shall be used if wind conditions could affect the quality of the installation.
3) Application

i. **Base Coat**

a. The base coat shall be applied the same day as the polyurethane foam when possible. If more than 24 hours elapse prior to the application of the base coat, the polyurethane foam shall be inspected for UV degradation, oxidation, and contaminants. The manufacturer's recommendations shall be followed to prepare the foam surface before coating applications.
b. The base coat shall be applied at a uniform thickness with the rate of application governed by the polyurethane foam surface texture. Coatings shall be applied at a rate to achieve the minimum dry film thickness (DFT) specified by the protective coating manufacturer.
c. The coating shall be allowed to cure and be inspected for pinholes, thinly coated areas, unsecured areas, and other defects. Defects shall be corrected.

ii. **Top-Coat and/or Subsequent Coat**

a. Inspect the base coating for defects and thin coating. Correct defects.
b. Subsequent coating shall be applied in a timely manner to insure proper adhesion between coats.

iii. Final coat shall be inspected for defects and thin coating. Correct defects in accordance with manufacturer's recommendations.

5. **Field Control, Evaluation, and Commissioning:**
    a. Inspect installation and verify work is complete and properly installed.

Section 07 60 00 – Flashing and Sheet Metal

1. **Overview:**
    a. Formed roof drainage sheet metal fabrications.
    b. Formed low-slope roof sheet metal fabrications, including cleats, copings, edge flashings, wind-clips, skirt flashings, two-piece base of wall flashings, and sheet metal backing.
    c. Formed wall and opening sheet metal fabrications, including sill pans, transition flashings, head flashings.
    d. Rooftop equipment pad covers.
    e. Splash blocks.
2. **Performance Requirements:**
    a. Quality Assurance
        1) Mock-ups
        2) Standards and certifications
    b. Sustainability
    c. Submittals
        1) See Submittal Register, Appendix II
    d. Warranties
        1) See Submittal Register, Appendix II

3. **Product Requirements:**
    a. **Base Flashing, Counterflashing, Flashing Receivers, and Penetration Flashings:** Fabricate from minimum 20 oz./sq.ft. copper, or 0.032–inch– to 0.022–inch–thick galvanized steel.
    b. **Roof-Drain Flashing:** Fabricate from minimum 20 oz./sq.ft. zinc-tin alloy-coated copper.
    c. **Valley Flashing:** Fabricate from minimum 20 oz./sq.ft. copper, or 0.028–inch–thick galvanized steel.
    d. **Parapet Scuppers:** Minimum 16 oz./sq.ft. copper; fabricate scupper of dimensions required with closure flange trim to exterior, 4–inch–wide wall flanges to interior, and base extending 4 inches (100 mm) beyond cant or tapered strip into field of roof. Fasten gravel guard angles to base of scupper.
    e. **Roof Edge Flashing (Gravel Stop) and Fascia Caps**: Fabricate in minimum 96–inch–long, but not exceeding 10–foot–long, sections. Furnish with 6–inch–wide joint cover plates.
    f. **Through-Wall Flashing:** Fabricate continuous flashings in minimum 96–inch–long, but not exceeding 12–foot–long, sections, under copings, at shelf angles, and other areas where required.
    g. **Discontinuous Lintel, Sill, and Similar Flashings:** Fabricate to extend 6 inches beyond each side of wall openings. Form with 2–inch–high end dams.

4. **Installation Requirements:**
    a. Comply with SMACNA's "Architectural Sheet Metal Manual" for fabrication and installation.
    b. Anchor roof edge flashing to resist uplift and outward forces according to recommendations in FMGlobal Loss Prevention Data Sheet 1–49 for specified wind zone and as required for project.

5. **Field Control, Evaluation,** and **Commissioning.**
    a. Inspect installation and verify work is complete and properly installed.

Section 07 84 00 – Firestopping

1. **Overview:**

    a. Firestopping for joints between edges of fire-resistive-rated floor assemblies and exterior curtain walls.

b. Fire-Resistive Joint Sealants in and Between Fire-Resistive-Rated Constructions: Provide systems with assembly ratings equaling or exceeding the fire-resistive ratings of construction that they join, and with movement capabilities and L-ratings as required.

2. Performance Requirements:

a. Quality Assurance

1) Mock-ups
2) Independent testing laboratory's listed assemblies with integrity ratings equaling or exceeding fire-resistive ratings of floor or floor/ceiling assembly forming one side of joint.
3) Provide firestopping systems with current ICC-ES reports, produced and installed to resist the spread of fire and the passage of smoke and other gases in compliance with California Building Code and UL requirements.

b. Sustainability

c. Submittals:

1) Submit evaluation reports from ICC Evaluation Service evidencing fire-resistive joint systems' compliance.
2) Submit evidence of fire-resistive joint systems' compliance with ICC Evaluation Service Acceptance Criteria AC30, from ICC Evaluation Service.
3) See Submittal Register, Appendix II.

d. Warranties

1) See Submittal Register, Appendix II.

3. Product Requirements:

a. Acceptable Manufacturers: Hilti and 3M.

4. Installation Requirements:

a. Identify firestopping with pressure sensitive, self-adhesive, preprinted vinyl labels. Attach labels permanently to surfaces of penetrated construction on both sides of each firestopping installation where the labels will be visible to anyone seeking to remove penetrating items or firestopping.

5. Field Control, Evaluation, and Commissioning:

a. Inspect installation and verify work is complete and properly installed.

DIVISION 08 – OPENINGS

GENERAL: Any deviation or modification impacting exterior appearance, facade systems, windows, doors, glazing, or building envelope systems shall require review and approval by Caltech Facilities Planning, Engineering & Architecture and the Director prior to implementation.

Section 08 14 00 – Wood Doors

1. **Overview:**
   - **a.** Interior Doors
     - **1)** Select door products and finishes for ease of maintenance and durability, with a uniform level of quality throughout the project.
     - **2)** Match existing adjacent doors in remodeling projects.
     - **3)** Review security requirements with Caltech Security department.
2. **Performance Requirements:**
   - **a.** Quality Assurance
     - **1)** Mock-ups
     - **2)** Standards and certifications
   - **b.** Sustainability
   - **c.** Submittals
     - **1)** See Submittal Register, Appendix II
   - **d.** Warranties
     - **1)** Manufacturer's warranty
     - **2)** See Submittal Register, Appendix II
3. **Product Requirements:**
   - **a.** Provide solid core doors. Hollow core wood doors are not permitted.
4. **Field Control, Evaluation, and Commissioning:**
   - **a.** Inspect installation and verify work is complete and properly installed.

Section 08 33 43 – Overhead Coiling Smoke Curtains

1. **Overview:**
   - **a.** Protection of the elevator hoist way entrances in compliance with CBC 3006.3, 3 or 5.
   - **b.** Retrofit existing elevator hoist way entrances/lobbies to comply with code.
     - **1)** **Smoke Barrier**: Provide smoke containment feature(s), where required, to restrict the movement of smoke from the elevator shaft to the occupied areas.
2. **Performance Requirements:**
   - **a.** Quality Assurance
     - **1)** Mock-ups
     - **2)** Standards and certifications
   - **b.** Sustainability
   - **c.** Submittals
     - **1)** See Submittal Register, Appendix II
   - **d.** Warranties – manufacturer's warranty
     - **1)** See Submittal Register, Appendix II

3. **Product Requirements:**
   a. Model 400 by Smoke Guard, Inc., 187 N. Maple Grove, Boise, ID 83704. www.smokeguard.com
   b. McKeon Door Company: Firefighter Series Model D200E
4. **Installation Requirements:**
5. **Field Control, Evaluation, and Commissioning:**
   a. Inspect installation and verify work is complete and properly installed.

Section 08 44 00 – Curtain wall and Glazed Assemblies

1. **Overview:**
   a. Section includes thermally broken glazed aluminum curtain walls.

2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
   b. Sustainability
   c. Submittals
      1) See Submittal Register, Appendix II
   d. Warranties
      1) Manufacturer's warranty
      2) See Submittal Register, Appendix II

3. **Field Control, Evaluation, and Commissioning:**
   a. Testing: At a minimum, before installation of interior finishes has begun, a minimum area of 75 feet by one story of curtain wall systems designated by design professional shall be tested according to AAMA 501.1.
      1) Assembly shall incorporate representative details and all components of the proposed design.
      2) Assembly shall not evidence any water penetration.
      3) Other tests may be necessary depending on the complexity of the design.
   b. Inspect installation and verify work is complete and properly installed.

Section 08 50 00 – Windows

1. **Overview:**

   a. Select window products and finishes for ease of maintenance and durability, with a uniform level of quality throughout the project.
   b. Energy conservation must be given prime consideration when incorporating fenestration into building design. Shading, orientation, low-emissivity glass, insulating glass, and thermally broken frames shall be given consideration as potential energy conservation methods. When insulating glass is used, it shall be hermetically sealed to prevent condensation between the two layers of glass and shall have a 10–year warranty.
   c. Provisions shall be made to allow for exterior cleaning of all glass with minimum inconvenience and hazard (e.g., double-hung windows or windows that open into the building). Provide swing stage or other similar connections to facilitate window washing where height exceeds 40 feet and reach from nearest ground access exceeds 30 feet.
   d. Glass shall be heat-strengthened, unless tempered is required by code, or for safety / security reasons.
   e. Retain and restore existing windows when architecturally significant.
   f. If new steel windows are required to match existing, provide windows with thermal break to comply with code.

2. **Performance Requirements:**

   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
   b. Sustainability
   c. Submittals
      1) See Submittal Register, Appendix II
   d. Warranties
      1) Manufacturer's warranty
      2) See Submittal Register, Appendix II

3. **Product Requirements:**

4. **Installation Requirements:**

5. **Field Control, Evaluation, and Commissioning:**

   a. Inspect installation and verify work is complete and properly installed.

Section 08 71 00 – Door Hardware

1. **General:**

   a. **Mandatory Meetings**: Design professional shall request a hardware meeting with Campus Lock Shop to determine specific existing site requirements and standards.

PART I - GENERAL

1.1 SUMMARY

1. **Section Includes:**

   a. Door hardware for aluminum, metal, and wood doors.
   b. Thresholds, weather-stripping, coordinators, astragals, and door seals.
   c. Electrified hardware, including power supplies, power-operated door openers, and card access controllers.
   d. Miscellaneous accessories and trim, including restroom door or toilet compartment hardware.

2. **Related Sections/Divisions:**

   a. Section 08 11 00 “Metal Doors and Frames”
   b. Section 08 14 00 “Wood Doors”
   c. Section 08 41 13 “Aluminum-Glazed Entrances and Storefronts”
   d. Section 10 28 00 “Toilet, Bath, and Laundry Accessories”
   e. Division 26— Electrical

1.2 REFERENCE STANDARDS

1. **Refer to appropriate section for information concerning availability and use of references.**

   a. ADA — American with Disabilities Act — Public Accommodations — Title III
   b. ANSI/BHMA A156 — Product Listing
   c. ASTM E152 — Methods for Fire Tests of Door Assemblies
   d. ASTM E283 — Standard Test Methods for Rate of Air Leakage through Exterior Windows, Curtain Walls, and Doors
   e. CRC — California Building Code and Local Jurisdiction Having Authority (JHA)
   f. CCR — California Code of Regulations Title 24
   g. DHI — Recommended Locations for Architectural Hardware for Standard Steel Doors and Frames

h. ICC A117.1 – Standard for Accessible and Useable Building and Facilities
i. ITS — Intertek Testing Services (Warnock Hersey)
j. NFPA 80 — Fire Doors and Windows
k. NFPA 101 — Life Safety Code
l. NEPA 105 — Installation of Smoke-Control Door Assemblies
m. NFPA 252 — Fire Test of Door Assemblies
n. NWWDA: — I.S.1-A National Wood Window and Door Association
o. SDI–107 Hardware on Steel Doors (Reinforcement/Application)
p. UL — Underwriters Laboratories 305 Panic Hardware
q. UL 10B — Fire Tests of Door Assemblies
r. UFAS — Uniform Federal Accessibility Standards

1.3 SUBSTITUTIONS

1. References are used to establish minimum standards of utility and quality. Unless approved otherwise, furnish only the specified products.

   a. Requests for substitutions to be in accordance with Division 01 — General Requirements and are to be in writing and hand-delivered and approved by Caltech Lock Shop. Approvals will be issued in an addendum at least ten days prior to hide opening. There will be no exemptions to this requirement if submitted after bid opening.
   b. All requests to be accompanied by two copies of the manufacturer's brochures and a physical sample of each item in appropriate design and finish.

2. Items listed with “no approved equal” are requested by the Caltech Lock Shop to match existing building standards. Substitutions will not be considered.

3. Should the contractor make substitutions without written consent of the design professional and Caltech Lock Shop, contractor shall remove substituted hardware, replacing same with the specified hardware at no additional cost to Caltech.

1.4 SUBMITTALS

1. **Products Data:** Submit manufacturer’s technical product data for each item of hardware. Show finishes, sizes, catalog numbers and pictures, and instructions for installation and maintenance. All submittals to be approved by Caltech Lock Shop prior to ordering.

2. **Pre-Submittal Conference:** Prior to the submittal of the hardware package, contractor shall arrange a conference between hardware supplier, door supplier(s), installers, and related trades to review materials, procedures, and hardware mounting locations, electrical components, and related work.

3. **Hardware Shop Drawings and Schedule:** Submit copies of hardware schedule organized into “hardware sets,” which shall conform to DHI’s “Recommended Procedures for Processing Hardware Schedules and Templates.” Schedule shall reflect complete designations of all hardware items required for each door or opening and other miscellaneous hardware. Include the following information:

   a. Type, style, function, size, quantity, and finish of each hardware item
   b. Name, part number, and manufacturer of each item
   c. Fastenings and other pertinent information
   d. Locations of hardware set cross-referenced to location on drawings both on floor plans and in door schedule
   e. Explanation of all abbreviations, symbols, and codes contained in hardware schedule
   f. Mounting locations for hardware

g. Door and frame sizes and materials
h. Include a list of all manufacturers used and their nearest representative, with contact name, address, and phone number.
i. Unless requested, metal and wood doors to be specified with internal blocking and/or metal reinforcing for surface hardware.
j. **Keying Schedule**: Submit separate detailed schedule indicating clearly how the Campus Lock Shop's final instructions on keying of locks has been fulfilled, subject to Campus Lock Shop's instructions.
k. Wiring diagrams for electrified hardware
l. See Submittal Register, Appendix II.

4. **Project Closeout Submittals:**

a. Two copies of factory bitting list and keying schedule
b. Two copies of manufacturer's product data for each type of hardware product
c. One copy of approved door and door hardware shop drawings and schedules
d. In addition to hard copies, provide electronic submittals in PDF format.

1.5 MAINTENANCE MATERIAL SUBMITTALS

1. **Hardware:** At job completion, supply to Caltech Lock Shop:

a. One percent extra of each item of hardware furnished for the project, but not less than one of each item.
b. One-hundred key blanks of each section (keyway) furnished.

2. **Tools:** Provide one set of installation and adjustment tools and one set of maintenance manuals for locksets, door closures, panic devices, and electrical components.

1.6 QUALITY ASSURANCE

1. **Manufacturer Qualifications:**

a. The hardware sets listed in the hardware schedule are prepared to establish typical door hardware requirements. Should any door or item be omitted from schedule, provide such door or item same as required for similar application.
b. **Supplier Qualifications**: Must be recognized Southern California–based factory direct contract distributor with a minimum five years of experience. Typical hardware sets to be comprised of hinges, panic device, trim, door closure, overhead stop if detailed, flat goods, threshold, sweep, drip cap, and perimeter jamb seals, or as specified for the project.

2. Errors requiring replacement material or repair, including labor, shall be corrected at no additional cost to the Owner.

3. **Post-Installation Policing**: Hardware specification writer, hardware distributor, contractor, Caltech Lock Shop, and design professional to determine compliance with the hardware specifications and campus standards.

4. **Regulatory Requirements:**

a. **Exit Doors**: Operable at all times from the inside without use of key or any special knowledge or effort.
b. **Fire-Rated Openings**: Provide hardware for fire-rated openings in compliance with the California Code of Regulations (CCR) Title 24, Part 2, California Building Code, and NFPA 80, and applicable accessibility requirements of CCR Title 24. This requirement takes precedence over other requirements for such hardware.

c. Provide only hardware that has been tested and listed by Underwriters Laboratories or other testing agency acceptable to the state fire marshal for the type and size of each door required and complies with the requirements of the door and door frame labels. Provide latching hardware, door closers, bearing hinges, and seals whether listed in the hardware schedule or not as required by the respective rated opening.

d. Where panic exit devices are required on fire-rated doors, provide supplementary marking on door label indicating "Fire Door to be Equipped with Fire Exit Hardware" and provide label on exit device indicating "Fire Exit Hardware." Exit devices in non-labeled openings to be listed for panic.

e. Closers are to have opening force adjusted to comply with current applicable handicapped accessibility requirements.

f. **Hardware Locations**: All hardware to be mounted between 30 inches and 44 inches. In general, refer to DHI's "Recommended Hardware Locations." Prior to issuing hardware templates, contractor and hardware suppliers shall review locations with the design professional and Campus Lock Shop.

5. General Requirements:

a. Coordinate as necessary with other trades to insure proper and adequate provision in the work of those trades for interface with work of this section.

b. All hardware shall be new and free from defects affecting both serviceability and appearance. Working parts shall be properly fitted, smooth operating, and without excessive play.

6. Electronic Hardware and Systems:

a. All electrical components, hardware, switches, and power supplies, operating as a system, to be supplied from a single manufacturer (to ensure compatibility) unless otherwise specified in the hardware schedule.

b. Electrified hardware to be as specified. Specifications requiring electrified products shall be coordinated with the approval and assistance of the Caltech Lock Shop and Caltech Security department.

c. Before electrically controlled or operated hardware is ordered, voltages and wiring details shall be coordinated with the contractor and all related trades.

d. **Wiring Diagrams**: Provide complete wiring diagrams for each opening requiring electrified hardware, including openings where only magnetic hold-opens are specified. Provide a copy with each hardware schedule submitted for approval. Provide other copies with delivery of hardware to jobsite and to Caltech Lock Shop at job completion.

e. All electrical components to be listed by opening in the hardware submittals.

f. **Operational Descriptions**: Provide complete operational descriptions of electronic components listed by opening in the hardware submittals. Operational descriptions to detail how each electrical component functions within the opening, incorporating all conditions of ingress and egress. Provide a copy with each hardware schedule submitted for approval. Supply another copy with delivery of hardware to jobsite and a duplicate to Caltech Lock Shop at job completion.

1.7 DELIVERY, STORAGE, AND HANDLING

1. Acceptance at site: Individually package each unit of finish hardware, complete with proper fastenings, fittings, and other devices, clearly marked on the outside to indicate contents and specific location for installation.

2. Delivery: Deliver hardware items to job site, except all MEDECO lock hardware and supplies to be delivered directly to Caltech Lock Shop**.**

3. Contractor to make available a secure location protected from weather and theft.

4. Contractor is fully responsible for hardware until job completion and sign-off.

1.8 PROJECT CONDITIONS

1. **Coordination:** Coordinate hardware with other work. Furnish hardware items of proper design for use on doors and frames of the thickness, profile, swing, security, and similar requirements indicated, as necessary for proper installation and function, regardless of omissions or conflicts in the information on the contract documents.

2. Upon request, check the shop drawings for doors and entrances to confirm the adequate provisions will be made for the proper installation of hardware.

1.9 EXISTING BUILDINGS (RETROFIT)

1. **Coordination and Design of Existing Buildings:** Locks, panics, closures, and other related hardware (in addition to keying) shall be directly approved by the Caltech Lock Shop.

2. **Building Survey:**

   a. Contractor is responsible for field survey of door, frames, and hardware to determine compatibility of specified hardware, including but not limited to locksets, panic devices, strikes, flushbolts, overhead stops, coordinators, closers, thresholds/seals, all electrical hardware, and hinge sizes and weights.
   b. Existing doors and frames to be modified for hardware as permitted by UL, WHI, and authorities having jurisdiction. Where required, contractor shall cut and weld reinforcements to existing jamb and doors, if reused, for listed hardware as applicable and required. Contractor to patch, sand, and repaint/stain door/frame surfaces affected by the removal of existing hardware. Related costs to field modify existing frames and/or doors shall be part of the contractor's base bid.
   c. Intertek Testing Service inspection and certification required for the modification of labeled doors and frames. Contractor is responsible for contracting and coordinating this required labeling service.
   d. Unless directed otherwise, contractor to modify all exterior openings to meet ADA change in elevation threshold requirements. Contractor to survey and, where necessary, apply concrete or pavement where applicable and approved by the design professional. Work shall comply with minimum ADA requirements as well as create a flat subsurface for specified thresholds.

3. **Existing Hardware:** Contractor shall deliver all removed/existing hardware to the Caltech Lock Shop.

4. **Unused Hardware at New Construction:** Contractor shall deliver all unused hardware to Caltech Lock Shop.

1.10 WARRANTY

1. In addition to the two-year general guarantee required, furnish to the campus a guarantee against defects in materials and workmanship for the periods of time specified below from the date of acceptance. The guarantee shall be signed by an authorized representative of hardware manufacturer and the contractor. See Submittal Register. Appendix II.

   a. Closures: 10 years.
   b. Exit Devices: 1 year.
   c. Locks: 1 year (5 years for FW10L).

PART 2 - PRODUCTS

2.1 MANUFACTURERS

1. Items of door hardware required for each door are indicated in the hardware schedule at the end of this division and the door schedule on the drawings.

2. Only Grade 1 hardware is acceptable.

2.2 HINGES:

1. **Manufacturers:**
   a. McKinney Products Company, an ASSA ABLOY Group company
   b. Stanley Commercial Hardware, a division of Allegion
   c. Pemko Manufacturing Co., an ASSA ABLOY Group company
   d. Markar Architectural Products, Inc., an ASSA ABLOY Group company

2. **Hinges:** BHMA A156.1.
   a. Provide full mortise five-knuckle template type, with non-rising loose pins, and flat button tips, unless otherwise scheduled.
   b. Hinge size shall be as scheduled, except where necessary to keep door leaf clear of wall, casings, jambs, or reveals in door openings; furnish wide throw or swing-clear style hinges.
   c. Furnish a minimum of three hinges for doors to 90 inches high and one additional hinge for every 30 inches of height or fraction thereof.
   d. **Exterior Door Hinges**: Stainless steel (or brass/bronze as required), Oilite, or ball bearing with non-removable pin (NRP) at out-swinging doors, extra heavy duty, or heavy duty as required. Review with Caltech Lock Shop.
   e. **Interior Door Hinges**: Steel, Oilite, or ball bearing type, extra heavy duty, heavy duty, or plain bearings are required.

3. **Continuous hinges:** BHMA A156.26.
   a. All hinges to be one manufacturer as hereafter listed for continuity of design and consideration of warranty.
   b. All hinges to be non-handed and completely reversible.
   c. Hinge line to be available in concealed flush mount with or without inset, full surface and half surface as specified or required.
   d. All concealed hinges to be available in standard-, heavy-, and extra heavy-duty weights.
   e. All full surface and half surface hinges in standard- and heavy-duty weights as specified.
   f. All hinges to be factory cut for door size.
   g. All hinges to be available in clear and dark bronze anodized finishes as required.

2.3 PIVOTS AND OVERHEAD CONCEALED CLOSURES:

NOTE: Hold open devices for doors to air-conditioned spaces to be reviewed by Facilities shops. Concealed overhead closures to be used only in the event standard surface units cannot meet design requirements. Floor closers to be used only where design requirements dictate and only then upon review and approval of Caltech Lock Shop.

1. **Manufacturers:**
   a. LCN Closers, an Allegion group company (surface closures and pivots).
   b. Rixson Specialty Door Controls, an ASSA ABLOY Group Company (floor closures and pivots).
   c. SARGENT Manufacturing Company, an ASSA ABLOY Group company (surface closures).
   d. Dor-O-Matic (Falcon), an Allegion group company (overhead concealed closures).
   e. Horton Automatics, a division of Overhead Door Corporation (Horton ADA operators only).

2. **Overhead Concealed (OHC) Closures:** Single acting unit for use with butt hinges or offset pivots and suitable for concealment within the door's header indicated on the drawings. Furnish center hung OHC as required by the respective opening.

3. **Pivots:** Fully mortised type of cast bronze with bronze Oilite bearings and corrosion protected hardened steel pins. Pivots shall have a positive stop, factory set to provide for the maximum degree opening permitted by trim of adjacent structure. Furnish special pins and longer spindles as may be required.

    a. **Pivot Quantities**: Furnish a minimum of three pivots for doors to 90 inches high and one additional pivot for every 30 inches of height or fraction thereof.

4. Floor closures are not to be specified unless approved by Caltech Lock Shop.

5. All exterior doors to be specified with overhead doorstops or floor devices as required by the specific opening conditions.

2.4 KEYING REQUIREMENTS

1. **Lock Cylinder Manufacturers:**

    a. Medeco Security Locks, Inc.; an ASSA ABLOY Group company.
    b. Schlage Primus for new construction (ground up only)

2. Contractor to arrange a keying conference with Caltech Lock Shop, design professional, and hardware supplier.

3. Furnish factory master keyed systems in accordance with lock manufacturer’s standards.

4. Keying systems are to be approved and/or designed by Caltech Lock Shop in writing.
5. Cylinder Installation:
   For new construction, Caltech Lock Shop will supply and install permanent cylinders as part of the project cost. Contractor shall coordinate this work with Caltech PM. Contractor is responsible for providing temporary construction cores.
   For renovation projects, Caltech Lock Shop will provide construction cores as part of the project cost. Contractor shall coordinate with Caltech PM.

NOTE: For work at existing buildings, Caltech Lock Shop to determine existing keying system and coordinate information as required for the project.

    a. Integrate with the existing master key systems as dictated by existing building standards and as directed by Caltech Lock Shop.
    b. Medeco lock cylinders are to be 6-pin standard pin tumbler. Keyway to be dictated by Caltech Lock Shop as required. No IC/removable core type cylinders should be used.
    c. Permanently stamp/inscribe each key with “Do Not Duplicate” as well as number that identifies cylinder codes, as per specifications from Caltech Lock Shop.

6. **Key Quantity:** Furnish change keys and master keys as required by Caltech Lock Shop. Deliver keys to Caltech Lock Shop.

7. Provide key codes (factory bitting list) to Caltech Lock Shop with sufficient expansion to double the size of the original project.

2.5 LOCKSETS

1. **Manufacturers:** All lockset, latches, electronic locksets, and trim to be the product of one manufacturer for the continuity of design and consideration of warranty.
   a. **SARGENT Manufacturing Company, an ASSA ABLOY Group company.**
   b. **Schlage Commercial Lock Division, an Allegion group company.**

   NOTE: Retrofit cylindrical lock with heavy-duty type Sargent 10Line levers in lieu of mortise application where existing conditions allow.
2. **Finish, design, and function should be Caltech standards to match existing.**
   a. US26D, US10B, or to match existing.
   b. Lever designs primarily SARGENT LNL design, Schlage LL, to match existing.
   c. Entrance functions with toggle standard, storeroom function on mechanical, custodial, etc.
   d. No deadbolt functions unless approved by Caltech Lock Shop.
   e. No classroom function locks unless approved by Caltech Lock Shop
3. **Locksets: Heavy-Duty Mortise type, function and trim design as listed or required.**
   a. Furnish locksets and latch sets with stainless steel. One-piece, 3/4-inch, anti-friction latch bolt, with latch guard protection.
   b. Guard bolt and ASA strike to be non-handed. Lock case to be constructed of 12-gauge steel.
   c. Lock shall be reversible without opening the case, and functions should be set only at the factory to insure proper operation.
   d. Locks to provide full latch bolt retraction with only 30 degrees lever depression.
   e. Locks shall exceed all performance specifications of ANSI A156.13 Grade 1 and meet cycle test of 2.5 million cycles and shall comply with CCR Title 24, Part 2.
   f. Lock to have through-bolted trim with floating spindles and wrought box strikes supplied with strikes.

   NOTE: Select trim design appropriate for the building except that levers shall comply with CCR Title 24 accessibility requirements. If escutcheon trim specified, furnish escutcheon designed to be flush with cylinder head. If rose trim specified provide cylinder trim rings/collar.
4. **Electrified Hardware:** Specifications requiring electrified hardware (panic devices, mortise and cylindrical locks, and electric strikes) shall be coordinated with Caltech Lock Shop. All electrified hardware must have REX (request to exit).

2.6 AUXILARY DEADLOCKS, STOREFRONT, AND COMBO LOCKS

1. **Manufacturers:**
   a. Simplex Unican (Mechanical Combo Locks).
   b. Adams-Rite Manufacturing. Co., an ASSA ABLOY Group Company (Storefront Aluminum Doors).

2.7 EXIT DEVICES:

1. **Manufacturers:** All exit devices, electronic exit devices, and trim to be the product of one manufacturer for continuity of design and consideration of warranty. Blumcraft hardware for glass door application is not acceptable under any circumstances.
   a. Von Duprin, an Allegion group company (mech. and electrified).
   b. SARGENT Manufacturing Company, an ASSA ABLOY Group company (mechanical).
   c. Precision Hardware, Inc., a division of Stanley Security Solutions, Inc. (electrified).
2. Exit devices shall be chassis mounted unit designed for ease of installation and maintenance. Rails to be solid cast material, not to exceed 3 inches in projection. Furnish exit devices with thru bolts unless otherwise specified.
3. **Exit Device Dogging:** Except on fire-rated doors, equip exit device with cylinder dogging device, as dictated by Caltech Lock Shop.
4. **Removable Mullion:** To be heavy-duty steel design. Acceptable manufacturer is Von Duprin, with cylinder type release, for security.
5. **Finish:** All exit devices will match existing building finishes. (US10B, US26D, US32D, US5).
6. Electrified exit hardware to be approved by Caltech Lock Shop.

2.8 FLUSH BOLTS AND COORDINATORS

1. **Manufacturers:**

   a. Glynn-Johnson, an Allegion group company.
   b. IVES Hardware, an Allegion group company.
   c. Trimco.
   d. Builders Brass Works (BBW), a Trimco company.
2. **Manual Flush Bolts:** Brass or bronze assemblies having a spring snap action lever, which will manually retract and project the bolt when moving to the proper position. The bolt shall have not less than 5/8–inch throw and shall have at least a 7/8–inch vertical adjustment. Provide extension rods of lengths required to position centerline of the operating lever 12 inches above the bottom of the door for bottom bolts and 72 inches above the bottom of the door for top bolts.
3. **Automatic Flush Bolts:** Brass or bronze assemblies that will automatically retract the bolts when the active door is open and project into the head frame when the active door is closed. Bolts shall have an effective throw not less than 3/4–inch and a minimum vertical adjustment of 1½ inches.
4. **Dustproof Strikes:** Brass or bronze assemblies with spring-loaded plunger that returns to floor or threshold level anytime the flush bolt is retracted.
5. Coordinators shall prevent the active door from closing before the inactive door by means of a lever and trigger mechanism. Provide unit of length recommended by the manufacturer for the width of the door.

2.9 OVERHEAD SURFACE MOUNTED CLOSERS:

1. **Manufacturers:** All surface closers to be the product of one manufacturer for the continuity of design and consideration of warranty.
   a. LCN Closers: an Allegion group company (surface closures and pivots).
   b. SARGENT Manufacturing Company; an ASSA ABLOY Group company (surface closures).
   c. Schlage AD-400 lock

   NOTE: Provide heavy-duty arms for all parallel arm closers, with compression stop where required at outswing mechanical, electrical, storage, etc. doors.
2. Closers shall be heavy-duty, surface mounted, hydraulic type, with high strength cast case. Full rack and pinion constructed of heavy steel. Closers to be reversible with arm and brackets of heavy forged steel. Provide thru bolts and grommets for mounting closers.
3. Closers to have adjustable spring power, which allows for closer sizing. Closers to have separate tamper resistant, non-critical regulating screw valves for closing speed, latching speed, and backcheck control features. Adjustable delay action available as an operation feature.
4. Closers shall have removable full size, non-corrosive, and high impact resistant covers with a maximum projection of 2–3/16 inches.
5. Closers, including covers, arms, and fasteners, shall all have finish to match other door hardware.
6. Closer arms to be forged steel, interchangeable with all closers specified on the project, for simplification of future owner maintenance considerations.
7. Supply appropriate arm assembly for each closer so that the closer body and arm are mounted on non-public side of door opening and on the interior side of exterior openings, except where required otherwise in the schedule.
   a. All parallel arm mounted closers to be factory indexed to insure proper installation.
   b. Furnish heavy-duty cold forged parallel arms for all exterior out-swinging openings.
8. **Adjustable Closing Force:** Closers shall be fully adjustable over a full range of sizes; except where closers are required to be accessible to the physically disabled, provide adjustable units complying with provisions for opening force and delayed action closing of CCR Title 24 and ADA Accessibility Guidelines for Buildings and Facilities. Pressure required to open doors shall comply with code and shall not exceed the following:
   a. **Fire-rated Doors**: 15 pounds maximum
   b. **Exterior doors**: 5 pounds maximum
   c. **Interior doors**: 5 pounds maximum
9. Where indicated and/or possible, doors are to swing to 180 degrees.
10. Unless requested, metal and wood doors to be specified with internal blocking and/or metal reinforcing for surface hardware. (Or thru bolts are to be used).

2.10 OVERHEAD DOOR CONTROL DEVICES (HOLDERS)

1. **Manufacturers:**
   a. Rixson Specialty Door Controls, an ASSA ABLOY Group company.
   b. SARGENT Manufacturing Company, an ASSA ABLOY Group company.
   c. Glynn-Johnson, an Allegion group company.
2. Overhead control devices may be surface or concealed type consisting of extruded brass or bronze channels, arms, and brackets with heavy tempered steel shock absorbing springs. Provide heavy-duty units with positive stop and hold open functions as scheduled. Furnish control device sized in accordance with the manufacturer's recommendation for widths of doors.

2.11 FIREGUARD SMOKE DETECTOR/MAGNETIC DOOR HOLDERS

1. **Manufacturers:**
   a. Rixson Specialty Door Controls, an ASSA ABLOY Group company.
   b. SARGENT Manufacturing Company, an ASSA ABLOY Group company.
2. Multi- and/or single-point hold-open units, adjustable range of 85 to 110 degrees, with trim permitting.
3. Where detector is required use integral photoelectric type with LED indicator.
4. Voltage to be specified per project requirements (12–24 VDC).

2.12 MISCELLANEOUS HARDWARE

1. **Manufacturers:**
   a. Quality
   b. Trimco
   c. Trimco/BBW
   d. IVES Hardware, an Allegion group company
   e. MAG
   f. Don-Jo Mfg., Inc.
2. **Bumpers, stops, and holders:** Stainless steel or brass/bronze casting of types scheduled and required.
3. **Push and Pull Plates:** Stainless steel or wrought brass/bronze. Provide manufacturer's standard fasteners for installation, thru bolted for matched pairs and for wood doors of particle core construction.
4. **Door Protection Plates:** Armor, kick, and mop plates shall be stainless steel or brass/bronze as required to match door hardware, not less than 0.050 inch thick, with beveled edges. Height shall be 36 inches for armor plates, 10 inches for kick plates, and 4 inches for mop plates.
5. Lock protectors shall be fabricated of stainless steel or brass/bronze as required to match existing building finish. All exterior out-swinging doors shall be protected with either a lock protector or full-length astragal(s).
6. **Silencers**: Grey/black rubber type for use in frames.

2.13 WEATHER STRIPPING AND SEALS

1. **Manufacturers:**
   a. National Guard Products
   b. Pemko Manufacturing Co., an ASSA ABLOY Group company
2. **Seals and Inserts:** Brush seals shall consist of densely compressed nylon filaments encased in high-quality aluminum retainers. All brush seals shall provide a 98% airtight seal, reducing the infiltration of light, air, and elements.
3. Where required, furnish closed-cell sponge silicone, dense neoprene, polyurethane, silicone, or vinyl for each assembly. Review with Caltech Lock Shop.
4. **Weather Stripping:** Provide exterior doors with door bottom, head, and jamb seals and thresholds as scheduled. Air leakage rate of weather-stripping for exterior doors shall not exceed 0.5 cubic feet per minute per linear foot of crack when tested in accordance with ASTM E283 at 0.57–psf differential air pressure.
5. **Fire- and Smoke-Rated Doors:** Provide door bottom, head, and jamb seals that have been tested in accordance with UL 1784 and comply with performance criteria for allowable air leakage specified in NFPA 105. In addition, assemblies shall have been tested in accordance with ASTM E152 and certified by Underwriters Laboratories to have no adverse effect on the fire rating of the door.
6. **Sound Retardant Doors:** Provide automatic door bottoms and adjustable head and jamb seals that have been tested in accordance with ASTM E90 in a configuration that uses the actual door assembly configuration, and provide an STC rating required for the project when evaluated in accordance with ASTM E413.

7. All thresholds must be in accordance with the requirements of ADA and ICC A117.1.

2.14 HARDWARE FINISHES

1. Provide matching finishes for hardware units at each door or opening, to the greatest extent possible. Match items to the manufacturer's standard finish for hardware for color and texture.
2. Provide protective lacquer coating on all exposed hardware finishes of brass, bronze, and aluminum.
3. The finish designations used in the hardware schedule are those specified in ANSI A156.18.

NOTE: Project requires material to be supplied in BHMA standards as dictated by the Caltech Lock Shop (US26D, US10B, US32, US5) for building standards.

PART 3 – EXECUTION

3.1 INSTALLATION

1. **Door Clearance:** Unless otherwise indicated or specified, provide the following clearances:
    a. **Floor Clearance**:
        1) **No Threshold**: 5/8–inch maximum above floor finish, or as limited by fire rated assembly requirements
        2) **Threshold**: 1/8–inch above threshold
    b. **Between Door/Frame at Head/Jambs**: 1/8–inch (3/32 at hollow metal hinge and strike jambs)
    c. **At Meeting Edges of Pairs of Doors**: 3/16–inch (1/8 when "Z" astragal is furnished)
    d. **At Transom Panels Without Bars**: 1/8–inch
2. **Hardware Mounting Heights:** All hardware to be mounted between 30 and 44 inches high and as indicated in the following applicable publications, except as specifically indicated or required to comply with governing regulations and except as otherwise directed by design professional.
    a. **Steel Doors and Frames (DHI)**: "Recommended Locations for Builders Hardware for Standard Steel Doors and Frames."
    b. **Standard Steel Doors and Frames**: as applicable
    c. **Door Top Rails**: Minimum dimension of 7–3/4 inches
    d. **Door Stiles**: Minimum dimension of 6 inches
3. Hardware shall be installed by a qualified tradesman skilled in the application of institutional grade hardware.
4. Care should be exercised not to mar or damage adjacent work. Damaged work will be repaired or replaced to the satisfaction of the design professional and/or owner at the expense of the contractor.
5. Provide adequate backing in stud partitions for the attachment of all respective hardware with special focus when installing wall stops.
6. Install each hardware item in accordance with manufacturer's instructions and recommendations. Do not install surface mounted items until finishes have been complete on the substrate. Set units level, plumb, and true to line and location. Adjust and reinforce the attachment substrate as necessary for proper installation and operation.
7. Pre-drill pilot holes in wood for screws. Drill and tap for surface mounted hardware on metal. Set hinge leaves snug and flat in mortises, turn screws to flat seat (do not drive).
8. Mount door closers and overhead stops and holders in accordance with the manufacturer's template for the degree of swing indicated on the drawings. Adjust closers, strikes, and stops after silencers, seal, and pressurization are complete. Drive hinge pins down and tighten set screws. Provide through bolts for mounting closers on wood doors.
9. Install locks and panics with cylinder keyways in proper position, with levers, roses, and/or escutcheons firmly affixed.
10. Set thresholds in waterproof sealant and secure with lead shields and countersunk screws of same finish as threshold.
11. Except for hinges, do not install hardware until completion of painting and finishing work.
12. **Electrical Components:**
    a. All wiring runs from one hardware electrical component to another electrified component to have shielded wiring.
    b. All electrical components mounted on doors to be capable of operation by 12 to 24 VDC current carried by means of continuous concealed circuit hinge, power transfer hinge, or loop (per Caltech Lock Shop's specifications).
    c. **Power Supply**: To be compatible with hardware manufacturer's specifications (regulated and filtered).
    d. **Installation of Electronic Hardware**: Comply with manufacturer's instructions for wiring, grounding, and shielding.
    e. **Field Quality Control of Electronic Hardware**: Manufacturer's field representative of electronic hardware to make visit to job site at the request of the design professional, contractor, or Campus Lock Shop for the purposes of monitoring compliance with manufacturer's installation requirements.

3.2 FIELD QUALITY CONTROL

1. During the installation of hardware, conduct periodic inspections in company with design professional and the hardware supplier. Remove and reinstall hardware improperly installed. At the completion of the work, conduct a final inspection.
2. Inspect installation and verify work is complete and properly installed.

3.3 ADJUSTING

1. Check and adjust each operating item of hardware and each door to ensure proper operation or function of every unit. Replace material that cannot be adjusted to operate freely and smoothly.
2. Adjust hardware so that moving parts operate freely without bind or excessive play. Installed hardware shall be free from paint, corrosion, or damage.
3. Final adjustments of locking devices/door strikes, door closer closing speed, latching speed, and back check, and related hardware to be completed after silencers and seals have been installed and after building pressurization has been completed.
4. Upon completion of installation and adjustment, provide required dogging keys, closer valve keys, lock spanner wrenches, and other factory furnished installation aids, instructions, and maintenance guides.
5. Contractor is responsible for the proper protection of all items of hardware until Caltech accepts the project as complete. All doors shall be self-closing, self-latching, and operate in compliance with ADA requirements.

3.4 HARDWARE SCHEDULES

6. **Schedule of Hardware Sets:** The hardware sets listed below indicate the items typically required to be installed on each door as scheduled on the drawings.

Typical hardware schedule format:

HARDWARE SET#					
DESIGNATION	**QTY.**	**DESCRIPTION**	**ITEM**	**FINISH**	**MFR**

DIVISION 09 – FINISHES

Exterior Finishes:

1. Select exterior wall products and finishes for ease of maintenance and durability, with a uniform level of quality throughout the project.
2. Submit a finish schedule and finish board(s) and maintenance instructions prior to completion of design development phase with samples of all exposed finish materials proposed by the design professional for Caltech approval.
3. Maintenance instructions to be furnished by contractor for all installed finishes.
4. The design of exterior enclosures within the Caltech Original Campus shall respect the contextual nature of the surrounding area.
5. When the scope of work involves lab spaces, provide balconies with demountable railings and double doors for installing and replacing large lab equipment.
6. During design development, PM will request mock-up of exterior wall elements as deemed necessary. During construction, provide a mock-up for client review and approval.
7. Comply with water testing requirements as part of the commissioning process. Review commissioning guidelines for more information.

Section 09 22 00 – Non-Structural Metal Framing

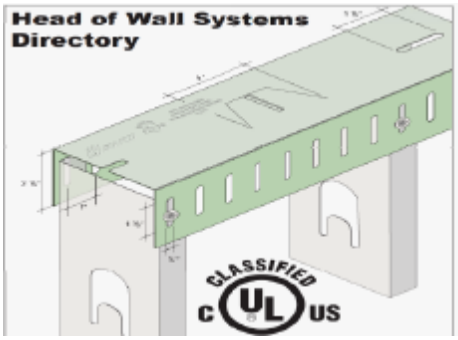
1. **Overview:**
   - **a.** Section Includes:
     - **1)** Non-load-bearing steel framing systems for interior partitions.
     - **2)** Suspension systems for interior ceilings and soffits.
     - **3)** Grid suspension systems for gypsum board ceilings.
     - **4)** Metal backing
2. **Performance Requirements:**
   - **a.** Quality Assurance
     - **1)** Mock-ups
     - **2)** Standards and certifications
       - **i. Steel Stud Framing Code Requirements / Wall Framing**:
         a. 2020 CBC section 2210.1 General. The design and installation of structural members and nonstructural members utilized in cold-formed steel light-frame construction shall be in accordance with AISI S200–AISI S230, AISI S100, and 2020 CBC Sections 2210.2 through 2210.7, as applicable.
         b. **Sill plate anchorage**: Shall be in accordance with ICC Evaluation Services Report #1752 and permit reviewed/issued plans/specifications.
         c. For additional information and illustrations visit the Steel Stud Manufacturers Association (SSMA) website, www.ssma.com.
   - **b.** Sustainability
   - **c.** Submittals:
     - **1)** See Appendix II, Submittal Register.
   - **d.** Warranties:
     - **1)** See Appendix II, Submittal Register.
3. **Product Requirements:**
   - **a.** CBC 2210 cold–formed steel light-framed construction general design, installation, and construction of structural and non-structural steel framing shall be in accordance with American Iron and Steel Institute (AISI), www.steel.org.

b. Steel stud walls supporting mechanical equipment or appliances shall be designed for seismic loads in accordance with the California Building Code referenced standard ASCE 7–05 for building components.

c. Slotted Slip/Deflection Track

1) Shall not be used for soffits and drop ceiling framing. "Hard screwing" not an acceptable alternative.

2) Slotted Slip/Deflection Track approved only for wall framing.



d. Corrosion Protection: Verify that load-bearing steel framing is protected with galvanized coating: See recommendations below.

Galvanized Coating:

Coating	Recommended for
G60	Indoor application where the environment is relatively dry.
G90	Applications where there is a potential for dampness from condensation.

Mils to Gauge conversion table:

Mils=Gauge
33=20
43=18
54=16
68=14
97=12
118=10

Wall fastening schedule:

Description of building element	Number and size of fasteners	Spacing of fasteners
Floor joist to track of load-bearing walls	2 No. 8 screws	Each joist
Wall stud to top or bottom track	2 No. 8 screws	Each end of stud, one per flange
Structural sheathing to wall studs	No. 8 screws per attachment schedule	6" o.c. on edges and 12" o.c. at intermediate supports

All the above screw sizes are minimum requirements.

e. Metal backing plate: minimum 6-inch-high by 0.053-inch-thick (16 gauge), as necessary, to support wall-mounted products and additional live loads, if any. Additional metal backing plates may be required for future wall-mounted products.

4. Installation Requirements

a. Steel studs and other structural members in load-bearing walls shall not be spliced. (Runner tracks may be spliced per approved plan or manufacturer's specifications.)

b. Field cuts or notches through the flanges or lips of any structural member not allowed.
c. Damaged members such as cracking in the steel at the bend radius location, and members with scaling of protective coating not allowed.
d. Welding of steel members is not permitted, unless approved. Exception: Special inspection by an approved agency for welding and re-coating with a zinc-rich paint.
e. Punched members shall not be used when unpunched members are specified.
f. Roll-formed (dimpled) framing materials are not approved for structural framing including ceilings and soffits. (See attached manufacturer's information).
g. Wall Framings:
1) Verify that gaps between the end of the stud and the track web are not greater than 1/8". Screw connections (See wall fastening schedule).
2) Verify screw size, spacing, and protective coating complies with approved plans.
3) Verify that screws are fully driven and have a min. penetration of (3) threads through the last member joined with no popped or damaged components.
4) Verify that screws penetrate individual components in the connection without causing separation/gap between the framing members.
5) Wall stud requires one screw at each flange/side.
h. Bracing Requirements:
1) Bracing intervals and methods for unsheathed flanges shall be determined by engineer of record or manufacturer's recommendations and shall be stated on approved set of plans.
2) Unsheathed flange shall be braced to resist rotation of the framing member when subject to lateral load (i.e. wall-hung cabinets, plumbing fixture, heavy cladding materials such as marble, stone, or tile)
3) Load bearing walls shall be sheathed on both sides or have approved bracing. Web stiffeners required at all bearing points.

5. Field Control, Evaluation, and Commissioning
a. Steel Stud Framing Inspection (General Requirements):
1) Identification (all framing members) CBC 2203.1
i. Identification shall be spaced not less than 48" o.c. The following information is to be included:

Size, type, flange, and thickness
Yield strength of steel
Galvanized coating weight
Manufacturer's name
ICC-ES/ICBO report numbers
Steel tracking numbers to identify master coil info
Date and time of production

Example of size, type, flange, and thickness:
362S125-33 means: 362=3–5/8" web depth
S= stud or joist C-shape.
Other markers may include: T= track; U= channel or stud no lips; F=furring angle or L header
125= 1¼–inch flange width
33= steel thickness 20 gauge in mils.

b. Inspect installation and verify work is complete and properly installed.

Section 09 23 00 – Gypsum Plastering

1. Overview:
a. Interior gypsum plasterwork on metal lath

b. For matching new construction with existing construction; patch and repair
c. Match application and appearance at all existing structures

2. **Performance Requirements:**
   a. Sustainability: Consider recycled content.
   b. Submittals
      1) Mock-ups required for each finish.
      2) See Appendix II, Submittal Register
3. **Product Requirements:**
   a. Expanded-Metal Lath: ASTM C847.
   b. Accessories:
      1) Cornerite
      2) Striplath
      3) Metal Trim: Galvanized steel, unless otherwise required by the project
      4) Plastic trim
      5) Aluminum trim
   c. Bonding compound
   d. Sound-attenuation blankets
   e. Plaster Mixes: ASTM C842
      1) Accelerators and Retarders: Use if required by project conditions.
4. **Installation Requirements**
   a. Plaster Finishes:
      1) Troweled
      2) Float
      3) Sprayed
      4) Textured
5. **Field Control, Evaluation, and Commissioning**
   a. Do not deviate more than plus or minus ¼ inch in 10 feet from a true plane in finished plaster surfaces, as measured by a 10-foot straightedge placed on surface.

Section 09 24 23 – Portland Cement Stucco

1. **Overview:**
   a. Exterior Portland cement plasterwork on metal lath
   b. **Existing interior**: Patch and repair; new construction matching existing interior plaster
   c. Match application and appearance at existing structures

2. **Performance Requirements:**
   a. Quality Assurance:
      1) Mock-ups. Provide mock-up for all projects.
      2) Comply with ASTM C 926
   b. Sustainability
   c. Submittals
      1) See Appendix II, Submittal Register
   d. Warranties
      1) See Appendix II, Submittal Register

3. **Product Requirements:**
   a. Diamond-Mesh Metal Lath: ASTM C847, self-furring, minimum 3.4 lb/sq. yd., fabricated from ASTM A653 G60 galvanized steel.

1) Paper backed lath is not permitted unless approved by Caltech per project.
2) Install according to ASTM C 1063.

b. **Accessories**: Galvanized steel.

4. **Installation Requirements:**
   a. Grout hollow-metal frames, bases, and similar work occurring in plastered areas with base coat plaster material, before lathing where necessary. Except where full grouting is indicated or required for fire-resistance rating, grout at least 6 inches at each jamb anchor.
   b. Finish plaster flush with metal frames and other built-in metal items or accessories that act as a plaster ground. Where casing bead does not terminate plaster at metal frame, cut base coat free from metal frame before plaster sets and groove finish coat at junctures with metal.
   c. Finish: Do not deviate more than plus or minus ¼ inch in 10 feet from a true plane in finished plaster surfaces, as measured by a 10-foot straightedge placed on surface.

5. **Field Control, Evaluation, and Commissioning:**
   a. Do not deviate more than plus or minus ¼ inch in 10 feet from a true plane in finished plaster surfaces, as measured by a 10-foot straightedge placed on surface.
   b. Inspect installation and verify work is complete and properly installed.

Section 09 29 00 – Gypsum Board

1. **Overview:**
   a. **Interior Gypsum Board, including the following types**:
      1) Type X
      2) Flexible Type for curved surfaces
      3) Ceiling type
      4) Moisture- and mold-resistant
      5) Impact-resistant
      6) Tile backing panels (board)

2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) **Standards**: Comply with applicable requirements of Gypsum Association (GA) as follows:
         a) GA-214: Recommended Levels of Finish for Gypsum Panel Products
         b) GA-216: Recommended Specifications for the Application and Finishing of Gypsum Panel Products
   b. Sustainability
   c. Submittals
      1) See Appendix II, Submittal Register.
   d. Warranties
      1) See Appendix II, Submittal Register.

3. **Product Requirements:**
   a. **Thickness**: Minimum 5/8-inch-thick, except two layers of ¼–inch-thick flexible gypsum board may be used for curved applications.
   b. **Typical Gypsum Board for Interior Partitions, Soffits, Ceilings, and Shaftliner**: ASTM C 1396/C 1396M.
   c. **Abuse-Resistant Gypsum Board**: ASTM C 629/C 1629M, for areas where greater resistance to abrasion, surface indentation, and impact is required. Level classification to be determined by the design professional.
   d. **Tile Backing Panels**: Glass-mat, water-resistant backing board complying with ASTM C 1178/C1178M or cementitious backer units complying with ANSI A118.9 and ASTM C 1288 or 1325.
   e. **Metal Trim**: Electro-galvanized or zinc-coated
      1) **Control Joints**: ½–inch-wide maximum joint size, faced with metal control joint accessory.

4. **Installation Requirements:**

a. **Level 5 Finish**: Provide on gypsum board with semi-gloss or gloss finish.
b. Install control joints in gypsum board ceilings where areas exceed 2,500 sq. ft. Distance between ceiling control joints shall not exceed 50 feet in either direction.
c. Install control joints in gypsum board partitions where distances exceed 30 feet and are not interrupted by doors or windows.
d. Apply metal trim, in longest lengths practicable, at exterior corners and at interior corners where gypsum board intersects metal or other dissimilar materials. Run trim straight and square with planes.

5. **Field Control, Evaluation, and Commissioning:**
   a. Gypsum board surfaces to be painted shall have no measurable variation in any 24-inch direction and a maximum variation of 1/8 inch in 10 feet when a straightedge is laid on the surface in any direction. Shim work as necessary to comply.

      Do not exceed 1/16-inch offset between planes of abutting gypsum board panels at edges or ends.

   b. Inspect installation and verify work is complete and properly installed.

Section 09 30 00 – Tiling

1. **Overview:**
   a. Ceramic and porcelain tile
   b. Stone tile
   c. Solid surfacing and stone thresholds
   d. Waterproofing membranes
   e. Crack isolation membranes
   f. Metal edge strips

2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
         i. Comply with applicable ANSI standards and current edition of the Tile Council of North America (TCNA) Handbook for Ceramic, Glass, and Stone Tile Installation.
   b. Sustainability
   c. Submittals
      1) Maintenance instructions at closeout
      2) Attic stock
   d. Warranties
      1) Manufacturer's warranty
      2) See Submittal Register, Appendix II

3. **Product Requirements.**
4. **Installation Requirements:**
   a. Perform concrete slab moisture testing in accordance with ASTM F1869 and/or ASTM F2170 as required by the tile manufacturer. Do not install tile until moisture conditions comply with the tile and setting material manufacturer's requirements.
   b. Floor surfaces in wet areas shall be sloped to the floor drain at a minimum of ¼ inch per foot (2%) to provide positive drainage and prevent standing water.

5. **Field Control, Evaluation, and Commissioning:**
   a. Inspect installation and verify work is complete and properly installed.

Section 09 51 00 – Acoustical Panel Ceilings

1. **Overview:**
   a. Suspended acoustical panel ceiling systems
      1) Suspended ceiling systems for acoustical tile and lay-in panels shall be standardized throughout the project utilizing standard exposed T-grid systems. This system shall be in labs and areas that require regular maintenance and access.
   b. Maintenance material submittals ("attic stock") for each color, type, pattern, etc. of the materials (and others, as appropriate) to be furnished by contractor. Each is to be packaged, protected, identified, and stored by the contractor at a location to be determined by Caltech and indicated in the specifications.
2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
         i. Suspended Ceilings (2020 CBC 2506.2.1/ASCE 7-05 13.5.6)
   b. Sustainability
      1) Manufacturers will be given preference when they provide documentation to support sustainable requirements for the following: Material ingredient transparency, removal of red list, ingredients per LBCV, life cycle impact information, low-emitting materials, and clean air performance.
   c. **Submittals**: see Appendix II, Submittal Register.
      1) **Product Data**: Submit manufacturer's technical data for each type of acoustical ceiling unit and suspension system required.
      2) **Samples**: Minimum 6-inch x 6-inch samples of specified acoustical panel; 8-inch-long samples of exposed wall molding and suspension system, including main runner and 4-foot cross tees.
      3) **Shop Drawings**: Layout and details of acoustical ceilings show locations of items that are to be coordinated with or supported by the ceilings. Plan must include engineering specifications for compression struts, wall attachments, and layout for seismic joints when areas exceed 2,500 square feet.
      4) **Certifications**: Manufacturer's certifications that products comply with specified requirements, including laboratory reports showing compliance with specified tests and standards. For acoustical performance, each carton of material must carry an approved independent laboratory classification of NRC, CAC, and AC.
      5) Attic Stock.
      6) Provide inspector with current ICC ES report for suspended ceiling system.
      7) Maintenance instructions to be furnished by contractor for all finishes.
      8) See Appendix II, Submittal Register.
   d. Warranties: see Appendix II, Submittal Register.
3. **Product Requirements:**
   a. **Acoustical Tile and Lay-in Panels**:
      1) Mineral fiber type with noise reduction coefficient (NRC) of no less than 0.70. Confirm with Caltech project management prior to selection of ceiling tile.
      2) **Acoustical Ceiling Panel Finishes**: For acoustical panel ceilings in laboratories, select flat, lay-in panel configuration. Reveal and tegular edge panels are not permitted in laboratories.
         i. The following are listed for basis of design as representative of the level of quality required and is not intended to exclude products that are of equal or better quality:
            a. **Tiles**: Armstrong Ultima Health Zone, 24"x24" or 24"x48", white, square lay-in tiles or approved equal.

b. **Regular heavy-duty T-grid**: Armstrong Prelude 15/16" XL Exposed T-grid system or approved equal.
c. **When gasketed T-grids are required**: Armstrong Clean Room 15/16" Exposed T-grid system or approved equal.

b. Suspension System Structural Classification: Heavy-duty system.

4. Installation Requirements

a. Seismic Design Category (SDC) D Requirements for Suspended Ceiling: Systems shall be designed and installed in accordance with ASTM C635, ASTM C636, and the CISCA for seismic zones 3–4 as modified by the following:

1) A heavy-duty T-bar grid system shall be used.

2) The width of the perimeter supporting closure angle shall be not less than 2 inches. Approved perimeter seismic clips may be used in lieu of 2-inch wall angle and shall be installed per manufacturer's instruction and ICC-ESR reports information.

3) In each orthogonal (orthogonal means "involving right angles") horizontal direction, one end of the ceiling grid shall be attached to the closure angle.

4) The other end in each horizontal direction shall have a 0.75–inch clearance from the wall and shall rest upon and be free to slide on a closure angle.

b. For ceiling areas exceeding 1,000 ft^2, horizontal restraint of the ceiling to the structural system shall be provided.

c. The tributary areas of the horizontal restraints shall be approximately equal. (Manufacturer may require vertical post every 12 square feet.)

1) EXCEPTION:

i. Rigid braces are permitted to be used instead of diagonal splay wires.

ii. Braces and attachments to the structural system above shall be adequate to limit relative lateral deflections at point of attachment of ceiling grid to less than 0.25 inch for the loads.

d. For ceiling areas exceeding 2,500 ft^2, a seismic separation joint or full height partition that breaks the ceiling up into areas not exceeding 2,500 ft^2 shall be provided.

1) EXCEPTION:

i. Structural analyses of the ceiling bracing system for the prescribed seismic forces that demonstrate ceiling system penetrations and closure angles provide sufficient clearance to accommodate the anticipated lateral displacement.

ii. Except where rigid braces are used to limit lateral deflections, sprinkler heads and other penetrations shall have a 2–inch oversize ring, sleeve, or adapter through the ceiling tile to allow for free movement of at least 1 inch in all horizontal directions.

e. Alternatively, a swing joint that can accommodate 1 inch of ceiling movement in all horizontal directions is permitted to be provided at the top of the sprinkler head extension.

f. Changes in ceiling plan elevation shall be provided with positive bracing per manufacturer's installation manual.

g. Cable trays, electrical conduits (EMT, MC cable, FMC, open air conductors, etc.), HVAC, and HVAC components shall be supported independently of the ceiling per ASCE 7-05 Chapter 13 requirements.

h. Integral Construction: As an alternative to providing large clearances around sprinkler system penetrations through ceiling systems, the sprinkler system and ceiling grid are permitted to be designed and tied together as an integral unit. (ASCE 7-05 13.5.6.3)

1) Such a design shall consider the mass and flexibility of all elements involved, including the ceiling system, sprinkler system, light fixtures, and mechanical (HVAC) appurtenances. Such design shall be performed by a registered design professional.

i. Perimeter Hangers: Terminal ends of each cross runner and main runner shall be supported independently a maximum of 8" inches from each wall or ceiling with number 12 gauge wire or approved wall support.

j. Vertical wires shall be attached to the suspension member and to the support above with a minimum of three turns.

k. Trapeze or equivalent device may be used where obstruction precludes direct suspension.

l. Seismic separation joints shall be installed per manufacturer's specifications and approved plans.

m. **Vertical hangers**: Suspension wires shall not be smaller than number 12 gauge spaced at 4' on center or number 10 gauge at 5' on center along each main runner.

n. Compression strut/seismic posts are typically required every 144 sq. ft., starting a maximum 6'-0" from perimeter with seismic wires (4) directions at max. 45 degrees from horizontal.

o. Partitions Tied to Suspended Ceilings (ASCE 7-05 13.8)

1) **General**: Partitions that are tied to the ceiling and all partitions greater than 6 ft. in height shall be laterally braced to the building structure.

i. Such bracing shall be independent of any ceiling splay bracing.

ii. Bracing shall be spaced to limit horizontal deflection at the partition head to be compatible with ceiling deflection requirements as determined in Section ASCE 7-05 13.5.6 for suspended ceilings and elsewhere in this section for other systems.

iii. **EXCEPTION**: Partitions that meet all of the following conditions:

a. The partition height does not exceed 9 ft.

b. The linear weight of the partition does not exceed the product of 10 lb. times the height (ft.) of the partition.

c. The partition horizontal seismic load does not exceed 5 psf.

p. Fire ratings shall comply with the requirements of the California Building Code chapter 7, UL listings, Office of the State Fire Marshal (SFM)'s listings, and installation per the manufacturer's suspended ceiling system installation manual.

q. The components and installation details must conform to the UL or SFM approval for the design number specified.

r. Custom designs that combine components from different approved designs but that have not been tested as a complete assembly are not acceptable.

s. For schools and essential services buildings, bracing assemblies are required for each 96 square feet.

t. The first bracing assembly is required not more than four (4) feet from each wall.

u. A minimum of one bracing assembly is required between any two adjacent expansion cutouts on runners being braced.

v. **Fire Separation Marking and Identification Requirements**:

1) Fire walls, fire barriers, fire partitions, smoke barriers, smoke partitions, and other walls required to have protected openings or penetrations shall be effectively and permanently identified with signs or stenciling, in accordance with CBC section 703.7.

2) **Such identification shall**:

i. Be located in accessible concealed floor, floor-ceiling, or attic spaces;

ii. Be repeated at intervals not exceeding 30 feet measured horizontally along the wall or partition; and

iii. Include lettering not less than 0.5 inch in height, incorporating the suggested wording: "FIRE AND/OR SMOKE BARRIER — PROTECT ALL OPENINGS," or other similar wording.

iv. **Exception**: Walls in Group R–2 occupancies that do not have a removable decorative ceiling allowing access to the concealed space.

w. **Electrical:**

1) Abandoned cables are not permitted to remain. CEC 800.52 (b).

2) Junction boxes and similar enclosures shall be accessible and shall maintain required working clearances, per CEC 314.29, 110.26(A).

3) Cables and raceways shall not be supported by ceiling grids, per CEC 300.11(A).

x. **Ceiling Tiles**:

1) Damaged or defective ceiling tiles shall be replaced.

5. Field Control, Evaluation, and Commissioning

a. Inspect installation and verify work is complete and properly installed.

Section 09 65 00 – Resilient Flooring

1. **Overview:**
   a. Resilient tile or sheet flooring
   b. Select floor finishes for ease of maintenance and durability, with a uniform level of quality throughout the project.
2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
   b. Sustainability
   c. Submittals
      1) Provide full-size sample of each flooring type. Submit a minimum of two full units of each color, pattern, and type for review and approval.
      2) Maintenance instructions to be furnished by contractor for all finishes.
      3) Maintenance material submittals (“attic stock”) for each color, type, pattern, etc. of the materials (and others, as appropriate) to be furnished by contractor. Each is to be packaged, protected, identified, and stored by the contractor at a location to be determined by Caltech and indicated in the specifications.
      4) See Submittal Register, Appendix II.
   d. Warranties
      1) See Submittal Register, Appendix II.
3. **Product Requirements:**
   a. **Laboratories**: Select heavy-duty commercial vinyl composition tile (12”x12”x1/8”) with 4” rubber top-set base.
      1) Except where special considerations dictate specialized flooring.
      2) Unless approved by Caltech PM, rolled rubber base is required to minimize joints.
      3) Coordinate with Caltech PM and Buildings & Grounds regarding application of floor sealer and finish for VCT flooring in accordance with flooring manufacturer's recommendations.
   b. **Vinyl Sheet Flooring**: Unbacked vinyl sheet floor covering complying with ASTM F 1913, 0.080 inch thick.
      1) Provide trowelable leveling and patching compound as recommended by flooring manufacturer.
      2) Use water-resistive type adhesive recommended by manufacturer. Adhesives shall comply with current SCAQMD VOC requirements.
      3) Install integral flash-cove base, where required. Extend flooring 6 inches up vertical surfaces. Support transitions between horizontal and vertical surfaces with cove strip. Terminate top edge with cap strip.
4. **Installation Requirements:**
   a. Perform relative humidity testing using in situ probes in accordance with ASTM F2170, prior to installation of finish flooring. Proceed with installation only after substrates moisture conditions comply with manufacturer requirements.
   b. New resilient flooring shall be extended under new fixed casework.
   c. Protect newly installed resilient flooring from damage, staining, moisture, and construction traffic in accordance with the flooring manufacturer’s recommendations. Maintain protection until owner occupancy.
5. **Field Control, Evaluation, and Commissioning:**
   a. Inspect installation and verify work is complete and properly installed.
   b. At project closeout, flooring shall be clean and free of defects.

Section 09 67 23 – Resinous Flooring

1. **Overview:** Seamless resinous flooring and integral cove base accessories.

2. **Performance Requirements:**
   a. Quality Assurance
      1) Provide mock-ups as required.
   b. Submittals
      1) Product data
      2) Physical samples for review of color and texture
      3) **Verification of Installer Qualifications**: Minimum five (5) years' experience in application of specified materials for projects of similar size and complexity
      4) **Contract Closeout Information**:
         i. Warranty
         ii. Maintenance data
      5) See Submittal Register, Appendix II.
   c. Warranties
      1) Written warranty signed by manufacturer and installer against defects and wear for a period of five (5) years, including but not necessarily limited to:
         i. Delamination from substrate
         ii. Loss of aggregate
         iii. Degradation of finish
         iv. Cracking and spalling
         v. Water penetration
      2) Deliver warranty to owner upon completion of installation.
      3) See Submittal Register, Appendix II.

3. **Product Requirements:**

   a. **Manufacturers or Approved Equals**: The following are listed for basis of design as representative of the level of quality required and are not intended to exclude products that are of equal or better quality.
      1) **Basis of Design**: Petra Products
      2) **Acceptable Manufacturers**:
         Dur-A-Flex
         Stonhart
         Sika Industrial Flooring
         Crossfield Products / Dex-O-Tex
         Dudick Inc.

4. **Installation Requirements:**

   a. General
      1) The system shall be applied in distinct steps as listed below:
         i. Substrate preparation
         ii. Primer coat
         iii. Vapor System
         iv. Top coat application.
         v. Finish coat application
      2) **Cove Base**: 6” high with ¾” radius and 1/8” thickness
      3) **Horizontal Surfaces**: shall be coated with an average thickness of 30 mils
      4) The finish shall be smooth. A skid-resistant surface that helps in the reduction of incidental slips and falls can be used with the option for the urethane finish.

5. **Field Control, Evaluation, and Commissioning:**

a. Flooring system contractor shall perform inspection of actual site conditions prior to start of work to verify that the work done under other sections meets all epoxy flooring system requirements. Contractor shall examine the areas and conditions where the epoxy flooring is to be installed and notify owner regarding the proper and timely completion of the work. Contractor shall not proceed with the work until unsatisfactory conditions have been corrected in a manner acceptable to the contractor, owner, and system manufacturer.

b. Inspect installation and verify work is complete and properly installed.

Section 09 68 13 – Carpet Tile

1. **Overview:** Modular carpet tile
2. **Performance Requirements:**
   - **a.** Quality Assurance
     - **1)** Mock-ups
     - **2)** Standards and Certifications
       - **i.** CRI–104 Standard for Installation of Commercial Carpet
       - **ii.** CRI Green Label program
   - **b.** Submittals
     - **1)** Product data
     - **2)** Provide full-size sample of each flooring type. Submit a minimum of two full units of each color, pattern, and type for review and approval.
     - **3)** **Contract Closeout Information**:
       - **i.** Warranty
       - **ii.** Maintenance data
     - **4)** Drawings that show pattern and layout in rooms
     - **5)** See Submittal Register, Appendix II.
   - **c.** Warranties
     - **1)** Written warranty for replacement of damaged or defective carpet or carpet stained by adhesives for a period of two (2) years.
     - **2)** Written warranty that material will not significantly degrade for a period of fifteen (15) years.
     - **3)** See Submittal Register, Appendix II.
3. **Product Requirements**:
   - **a.** Manufacturers, or approved equal: The following are listed for basis of design as representative of the level of quality required and are not intended to exclude products that are of equal or better quality:
     - **1)** **Acceptable Carpet Tile Manufactures**: Shaw Contract, Patcraft, Mohawk
     - **2)** **Acceptable Edging Strips**: Johnsonite
     - **3)** **Acceptable Adhesive**: LokDots adhesive tabs by Shaw Contract or approved equal
       - **i.** Carpet adhesive shall have VOC content of no greater than 50 g/L.
4. **Installation Requirements:**
5. **Field Control, Evaluation, and Commissioning**
   - **a.** Inspect installation and verify work is complete and properly installed.

Section 09 69 00 – Access Flooring

1. **Overview:**

a. Select raised flooring system with adequate loading capacity to support all dead and live loads to be imposed upon it. Coordinate with Caltech to determine loading requirements of access flooring.

2. Performance Requirements:

a. Quality Assurance

1) Mock-ups

2) Standards and certifications

a) Comply with ASCE 7 Minimum Design Loads for Buildings and Other Structures, Chapter 13, including 13.5.7.

b) Provide raised floor panels that inhibit fungus, mold, mildew, and gram-positive and gram-negative bacteria and that show no mold, mildew, or bacterial growth when tested according to ASTM D 3273 and evaluated according to ASTM D 3274 or ASTM G 21.

b. Sustainability

c. Submittals

1) Provide full-size sample of each flooring type. Submit a minimum of two full units of each color, pattern, and type for review and approval.

2) See Appendix II, Submittal Register

d. Warranties

1) See Appendix II, Submittal Register

3. Product Requirements:

4. Installation Requirements:

a. Installation Preparation:

1) Provide sealer on concrete substrate.

2) Seal underfloor air cavities at construction seams, penetrations, and perimeter to control air leakage when used as underfloor air plenum.

5. Field Control, Evaluation, and Commissioning:

a. Inspect installation and verify work is complete and properly installed.

Section 09 90 00 – Painting and Coating

1. Overview:

a. Exterior and interior painting and coating.

2. Performance Requirements:

a. Quality Assurance

1) Mock-ups

2) Standards and certifications

b. Sustainability

c. Submittals

1) See Appendix II, Submittal Register

d. Warranties

1) See Appendix II, Submittal Register

3. Product Requirements:

a. Exterior Architectural Coatings: Sherwin Williams SherLastic Low VOC, Elastomeric Coating A5-800 Series paint.

1) Exterior Historical Paint Color Standard: Sherwin Williams “Caltech San Simeon.” Obtain Caltech Director of Planning, Engineering & Architecture and Paint Shop’s approval for color formula when matching existing.

2) Exterior Historical Window Trim Color: Frazee, Aro-Thane semi-gloss custom color for Caltech: ZZ–64–228/ OLD COCOA.

b. Interior Painting:

1) **Interior Wall White Color Standard**: Dunn Edwards or Sherwin Williams Caltech Pure White SW 7005, eggshell finish.
2) Interior Ceiling White Color Standard: Dunn Edwards or Sherwin Williams Caltech Pure White SW 7005, flat finish.

c. Concrete Flooring:

1) Sealed Concrete: Provide clear sealer for exposed interior concrete floors where indicated. Coordinate sealer type, application method and maintenance requirements with Caltech PM and Buildings & Grounds prior to application.
2) Polished Concrete: Provide mechanically polished concrete with protective sealer. Coordinate gloss level, finish, and maintenance requirements with Caltech PM and Buildings & Grounds prior to application.

4. Installation Requirements:

a. Interior Painting: Drywall to receive one coat of primer and two coats of finish enamel, unless noticed otherwise.
b. Sealed or Polished Concrete Flooring: Provide field mock-up for approval prior to full application. Mock-up shall demonstrate surface preparation, finish level, and final appearance. Coordinate mock-up location with Caltech PM. Mock-up shall be reviewed and approved by Caltech PM and Custodial Shop prior to proceeding with work.

5. Field Control, Evaluation, and Commissioning:

a. Inspect installation and verification that work is complete and properly installed.

DIVISION 10 – SPECIALTIES

Section 10 11 16 – Markerboards

1. **Overview:**
   a. White Markerboards
2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
   b. Sustainability
   c. Submittals
      1) See Appendix II, Submittal Register
   d. Warranties
      1) See Appendix II, Submittal Register
3. **Product Requirements:**
   a. **Markerboards**: Acceptable markerboard types: back-painted glass or porcelain enamel steel with low-gloss finish and magnetic capability. Discuss any deviations, including wall talker specifications, with Caltech PM. Acrylic and melamine markerboards are not acceptable.
4. **Installation Requirements:** Mount writeable surfaces so the centerline of the writing surface measures 60 inches AFF, unless otherwise required for the intended use, adjacent conditions or as indicated by PD&C. Coordinate mounting height with adjacent features including furniture, casework, receptacle locations as well as accessibility requirements.
5. **Field Control, Evaluation, and Commissioning:**
   a. Inspect installation and verify work is complete and properly installed.

Section 10 14 00 – Signage

1. **Overview:**
   a. **Building Signage**: Review signage requirements with Caltech Safety Officer, with authorities having jurisdiction over the project, and with Planning, Design & Construction space information manager (Caltech must approve any exterior signage). Exterior signage may also have to be approved by the Finance, Facilities, and Infrastructure Committee of the Board of Trustees. See Appendix XXVII for exterior signage guidelines.
   b. **Site Signage**: Review signage requirements with Caltech project manager, with authorities having jurisdiction over the project, and with Planning, Design & Construction's space information manager.
   c. **Traffic Signage**:
      1) Provide porcelain enamel on steel signs with beaded text and symbols complying with the most recent requirements of the California Department of Transportation.
      2) At entry to parking areas, provide state-required signage, R110B (CA).
      3) At parking spaces, provide state-required signage, R99 (CA) and R99B (CA).
   d. Caltech requires all CBC and ADA signage requirements be met, at minimum, as required by code. Caltech reserves the right to require additional elements in signage design beyond code requirements.
   e. The design of all interior signs must be coordinated with and approved by space information in Planning, Design & Construction.
   f. Placement and design of external signage must be coordinated with, and approved by, space information and the architect in Planning, Design & Construction.
2. **Performance Requirements:**

a. Quality Assurance
1) Mock-ups may be required for project site signage. Consult with Caltech on a case-by-case basis.
2) **Standards and Certifications**:
a) Provide signs required by California Building Code (CBC). Comply with applicable provisions in the U.S. Architectural & Transportation Barriers Compliance Board's ADA Standards for Accessible Design. Sign on door per CBC, with corresponding wall sign and room number sign. Room number shall be on wall above the corresponding wall sign. Elements must have raised text and braille per CBC.
b) All signage needs to be reviewed and approved by Caltech; this includes project site signage.
b. Sustainability
c. Submittals
1) See Appendix II, Submittal Register
d. Warranties
1) See Appendix II, Submittal Register. Check with project manager and space information manager for signage warranty requirements per project.

3. **Installation Requirements:** All exterior building signage must be resistant to removal by unauthorized parties. All interior building signage must be securely affixed to surfaces to resist casual or unauthorized removal or seismic displacement.
4. **Field Control, Evaluation, and Commissioning:**
a. Inspect installation and verify work is complete and properly installed.
5. **Signage Schedule:**
a. **Room signage**: All interior room signs and wayfinding signs must be approved by the Planning, Design & Construction space information manager. Room signs should adhere to the following:
1) **Toilet Room and Door Signs**: Provide toilet room signs in accordance with California Building Code (CBC). Provide door-mounted geometric symbols and adjacent tactile identification signs where required by code. Coordinate room names and numbering with the Planning, Design & Construction Space Information Manager.
2) **Stair Signs**: Signs within a fire-rated stairwell shall identify each stairway, indicate whether there is roof access, the floor level, and the upper and lower terminus of the stairway. Signs at the entrance to the stairwell, or at the head and foot of the interior stairwell (if open), shall identify the room/location number at the top, with a pictogram of stairs in the middle, and the word "STAIRWAY" at the bottom. Signs at the entrance to, or at the foot or the head of the stairs, must have raised text and braille as per CBC (signs within the stairwell do not require raised text or braille).
a) 1/8-inch thick, hard phenolic ES plastic laminate and raised copy, Grade 2 (contracted) California braille.
b) **Color and Size**: As selected by design professional; sans serif letter style, Helvetica is preferred. Other fonts may be used upon approval by Planning, Design & Construction space information manager.
3) **Stairway Floor Level Identification Signs**: Provide signs at each floor level in all stairways and wherever required by California Building Code.
4) **Elevator Signs**: Room number with pictogram and word "ELEVATOR." Signs shall identify the room/location number at the top, with a pictogram of an elevator car in the middle and the word "ELEVATOR" at the bottom. All three elements must have raised text and braille per CBC.
a) **Text at Elevator**: "IN CASE OF FIRE, USE STAIRS"
5) **Evacuation Signs**: To be selected by design professional and approved by Planning, Design & Construction space information manager.
a) **Text**: Graphic signage indicating evacuation routes as required by CBC.
6) **Entry Decals**: Provide minimum-4-inch-square decal with International Symbol of Access (ISA), white on blue background with white border, applied to glass at accessible entry doors.
7) **Room Capacity Signs**: Color and material to be consistent with room number signs and must be approved by the Planning, Design & Construction space information manager.
a) **Text**: "MAXIMUM OCCUPANCY: _____ PERSONS"
b) **Size**: ¾–inch- to 1–inch-high letters (numbers shall be 1–inch high).
8) **Laboratory Signs**:
a) Manufacturer and design to be selected by design professional and approved by Caltech.
b) Refer to the latest "Laboratory and Workplace Safety Signs" document by Caltech EH&S Office:

https://safety.caltech.edu/documents/14124/Laboratory_and_Workplace_Safety_Signs.pdf

9) **Laboratory and Science Entrances**: Provide each interior laboratory entrance with a Caltech emergency information sign holder:
   a) Acrylic oversized 8½ by 11–inch holder, top feed with bottom stop. See Interior Signage Standards, Appendix XXVI.
   b) Caltech will provide inserts for holders with the following information:
      (1) Emergency contacts
      (2) "In case of Emergency dial 5000"
      (3) Hazards present
      (4) National Fire Protection (NFPA) diamond
      (5) Proposition 65 warning
10) **Radioactive Materials:**
   a) **Entrance**: Provide each laboratory where radioactive materials are used or stored with sign posted at the entrance bearing the radiation symbol and the words "**CAUTION, RADIOACTIVE MATERIAL.**"
   b) **Radiation Area**: Areas where radiation levels might expose a person to five millirems or more in any one hour shall be posted with a sign bearing radiation symbol and the words "**CAUTION, RADIATION AREA.**"
11) **Laser Lab, Entrance**:
   a) The entrance to a lab with class 2 and 3R lasers that do not exceed the maximum exposure limit for irradiance shall be posted with a sign bearing laser hazard symbol and the words "**CAUTION, LASER RADIATION.**"
   b) The entrance to a lab with lasers that exceed the maximum exposure limit for class 3b and 4 lasers shall be posted with a sign bearing laser hazard symbol and the words "**WARNING, LASER RADIATION.**"
12) **Magnetic Field, Entrance**:
   a) The entrance to a facility that contains a strong magnetic field shall be posted with a sign bearing magnet symbol and the words:

WARNING, STRONG MAGNETIC
FIELD
NO CARDIAC PACEMAKERS
NO NEUROSTIMULATORS
NO LOOSE METAL OBJECTS

13) **Gaseous Fire Suppression System, Entrance**: The entrance to a facility that contains a gaseous fire suppression system shall be posted with:

CAUTION
"This Area is Protected by *insert name for type of gas* System"
"In case of discharge exit from the protected area immediately."

14) **Biosafety, Entrance**: The entrance to a biosafety level 2 and 3 facility shall be posted with a sign bearing biohazard symbol and the words "BIOHAZARD." The sign shall include:
   a) Entry requirements (hazard identification and PPE requirement)
   b) Emergency contacts
15) **Donor Signage**: Embossed stainless-steel, flush plate with recessed stainless-steel letters or other signage as deemed appropriate by Caltech.
   a) **Letter Style and Mounting**: As determined by design professional and Caltech.
16) **Fire Extinguisher Signs**: Should project out from the wall and be visible throughout the room and include standard graphic design elements (pictograph) of a fire extinguisher. It should also be placed directly above the fire extinguisher's location. The sign itself should be an 8–inch x 8–inch blade-type sign. The background color should be red and the pictograph and any lettering should be white. The sign should be installed with an approved wall bracket at a height of 88 inches AFF (to the bottom of the sign) centered directly above the fire extinguisher box (if ceiling height and other conditions permit). Any exceptions regarding placement should be approved by the Caltech project manager and the space information manager.

17) **No Smoking Signs**: Smoking is not permitted in any campus building. No smoking signs must be posted at exterior doors. Smoking is not permitted within 25 feet of a campus building and Pasadena Municipal Code 8.78 should be included as the authorization on all non-smoking signs. Caltech has a standard design for non-smoking signs. Check with space information in Planning, Design & Construction for this design. No smoking signs should include a white cigarette with the red circle and slash superimposed on top and appropriate lettering specifying no smoking within a minimum of 25 feet from the building. Signs must be prominently displayed at all building entrances. Lettering must be visible from a minimum of 30 feet and must include a reference to the Pasadena Municipal Code 8.78.
18) **Eyewash, safety shower, and combination sign** should project out from the wall and be visible throughout the room and include standard graphic design elements (pictograph) identifying the emergency equipment. The sign itself should be a blade-type sign. The background color should be green and the pictograph and any lettering should be white. The sign should be installed with an approved wall bracket centered directly above the emergency equipment's location, at a height of 88" AFF (to the bottom of the sign) if ceiling height and other conditions permit. Any exceptions regarding placement should be approved by the Caltech Project Manager.
19) **Laboratory Signs**: Interiors of all occupied laboratory spaces are required to include a 9 x 6–inch clear sign holder to contain an instruction sheet as specified by the Caltech sustainability and space information offices. Sign holders shall be placed in locations to be specified by the space information manager. Sign *contents* will be specified by Caltech but sign inserts shall be provided by the project. Projects are responsible for providing inserts at all signs.

b. Room Numbering:

In all cases, room numbers shall be assigned by the space information manager at Caltech PD&C. This shall occur no later than the design development phase of a project. If rooms are added during later phases, the Caltech space information manager must assign the room numbers. Caltech uses a very precise and comprehensive space numbering system that resides in AiM and is accessed and updated through BSDS. Therefore, all spaces and locations have a unique identifying number; a room number cannot be repeated within a building. Many but not all of these identifying numbers must be posted. In addition to assignable rooms, Caltech requires unique posted room numbers for mechanical rooms, data closets, custodial spaces, restrooms, stairways, and elevators. When the location of a door to a room changes, that may impact the identification number for the room. Coordinate with space information in PD&C.

1) **Room numbering shall conform to the following requirements**:
   - **a)** Above ground floors shall be designated (from the ground up) as 1, 2, 3, etc.
   - **b)** Below ground floors shall be designated (from the top down) as B1, B2, etc.
   - **c)** All interior spaces must be designated by a room number.
   - **d)** Each room number within a building must be a unique combination of alphanumeric characters regardless of floor.
   - **e)** Room numbers and/or room suites for above-ground assignable rooms with doors entering off a common and/or publicly accessible hall shall be designated with 3-digit integer numbers reflecting floor and room number (such as 101).
   - **f)** Room numbers and/or room suites for below-ground assignable rooms with doors entering off a common and/or publicly accessible hall shall be designated with 3-digit integer numbers preceded by the letter "B" (such as B101).
   - **g)** Rooms within a suite (or within another room) shall share a room number followed by a letter suffix (such as 101A). Do not use hyphens.
   - **h)** Rooms within rooms within a suite (including closets) shall be designated by the room number followed by a letter and a number (such as 101A1). Do not use hyphens.
   - **i)** Rooms along a corridor shall be numbered with even numbers on east and south sides and odd numbers on west and north sides, to mirror the Pasadena street grid system. Individual room numbers must be approved by Caltech.
   - **j)** In order to allow for future modifications of space, room numbers may occasionally be non-sequential if there is a probability or likelihood of future changes (in the case of classrooms or other larger-sized rooms, neighboring rooms on one side of the hall may be 110, 120, 130, etc.).

k) Room numbering systems should include non-assignable rooms such as restrooms, custodial closets, and mechanical rooms.

l) Room numbers shall not include a leading zero.

m) Assignable room numbers shall not include numbers ending in "00" (such as 100 or 200 or B100). These shall be reserved for assignment by PD&C staff, preferably for non-assignable circulation areas.

n) Non-assignable spaces will have room numbers assigned by Caltech Planning, Design & Construction and are differentiated by a two-letter suffix depending on the purpose of the room, as follows:

(1) **CO – Corridors**: Corridor room numbers are not usually posted

(2) **DT – Data Rooms**: Wiring for central computer or data systems

(3) EL – Electrical Rooms

(4) **EV – Elevators:** Shafts shall be numbered on each floor and vertically consistent throughout the building such as 191EV, 291EV, 391EV, B191EV etc.)

(5) **JN – Janitor**: Custodial or housekeeping rooms (including storage of supplies)

(6) **LO – Lobby**: Publicly accessible lobbies or vestibules (numbers not usually posted)

(7) **ME – Mechanical**: Mechanical rooms or rooms housing specific machinery

(8) **PK – Parking**: Garages for vehicle parking

(9) RM – Men's Restroom

Note: Accessible restroom signs must include the International Symbol of Accessibility (ISA) as specified in CBC regulations

(10) RR – All-Gender, Gender Neutral or Single-User Restroom

Note: Accessible restroom signs must include the International Symbol of Accessibility (ISA) as specified in CBC regulations

(11) RW – Women's Restroom

Note: Accessible restroom signs must include the International Symbol of Accessibility (ISA) as specified in CBC regulations

(12) SH – Shower Facilities

(13) **ST – Stairs** and stairwells

(14) **TL – Telephone** systems (if both telephone and data, use "DT")

(15) **XX – Vertical shafts** for equipment or ductwork (counted at each floor level but not posted)

o) Donor-funded or special "named" areas shall be appropriately designated. Signage must be approved by PD&C space information manager.

p) Although not technically "rooms," covered, unenclosed areas (roofed walkways or porches that are open to the outside on one or more sides) shall also be identified and numbered so that when maintenance is needed or when gross space calculations are required, they can be included. Covered, unenclosed areas will be numbered with a CU suffix. Designations (numbers) shall be specified by the PD&C space information manager.

q) Roof or other open outdoor areas of the structure will also be assigned location numbers by the PD&C space information manager.

c. Stakeholders for Consultation:

1) Academics (Occupants)
2) Cost Studies
3) Telecommunications
4) Security
5) Key Shop
6) Maintenance Management
7) Mail and Deliveries
8) IMSS
9) Asset Management
10) Inclusion and Diversity

d. Refer to the Caltech standards for interior signage in Appendix XXVI.
Exterior signage guidelines can be found in Appendix XXVII.
Any deviation from the Caltech standards or guidelines should be determined in consultation with and approved by the Caltech PD&C information manager, architect, and building inspector.

e. Shop drawings identifying sign content, materials, shapes, and dimensions must be approved by the Caltech space information manager and architect prior to production.

f. Projects should develop wayfinding signage to complement code-driven signs. Restrooms and other service rooms should be especially easy to locate through wayfinding signage.

g. All projects should inform the space information manager of proposed space uses and configurations and obtain approval on room numbering.

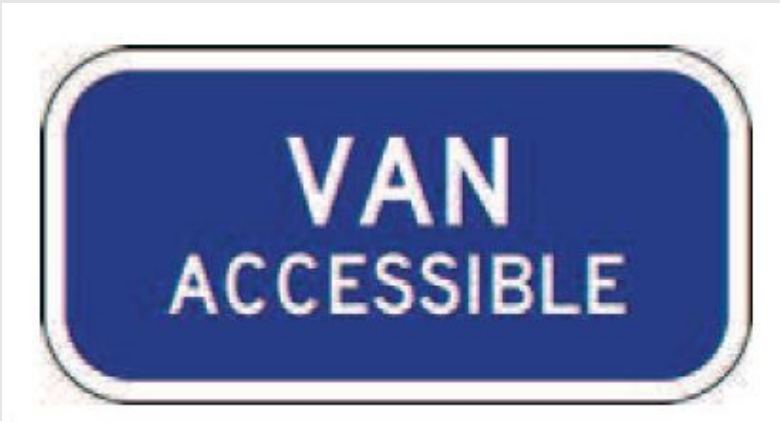
STATE OF CALIFORNIA – DEPARTMENT OF TRANSPORTATION
R99 (CA)
NOTE: For symbol details, see Standard Highway Signs, Appendix, "Handicapped"
COLORS: Border and Legend – White (Retroreflective)
Background – Blue (Retroreflective)



R99B (CA)
COLORS: Border and Legend – White (Retroreflective)
Background – Blue (Retroreflective)
https://dot.ca.gov/programs/safety-programs/sign-specs
http://www.dot.ca.gov/hq/traffops/signtech/signdel/specs/R99_R99B.pdf



R7-8b
COLORS: Border and Legend – White (Retroreflective)
Background – Blue (Retroreflective)



R100B (CA)
COLORS: Border and Legend – Black
Background – White (Retroreflective)


0.375"
0.625"
1.75"
1"C Typical
0.5" Typical
11.5"
24"
1.25"
2.5"
2.75"
1"C
3.25"
24"
UNAUTHORIZED VEHICLES PARKED
IN DESIGNATED ACCESSIBLE
SPACES NOT DISPLAYING
DISTINGUISHING PLACARDS OR
SPECIAL LICENSE PLATES ISSUED
FOR PERSONS WITH DISABILITIES
WILL BE TOWED AWAY
AT THE OWNER'S EXPENSE
TOWED VEHICLES
MAY BE RECLAIMED AT
CALTECH SECURITY
OR BY TELEPHONING
(626) 395-4701
MIN. FINE OF $250

Section 10 21 00 – Toilet Compartments

1. **Overview:**
   - **a.** Toilet compartments configured as toilet enclosures and urinal screens.
2. **Performance Requirements:**
   - **a.** Quality Assurance
     - **1)** Mock-ups
     - **2)** Standards and certifications, code compliant.
   - **b.** Sustainability
   - **c.** Submittals
     - **1)** See Appendix II, Submittal Register
   - **d.** Warranties
     - **1)** See Appendix II, Submittal Register
3. **Product Requirements:**

   a. Caltech project manager to approve partitions, particularly for all-gender restrooms.

   b. **Acceptable product for all-gender partitions**: Scranton Products Aria, or Caltech-approved equal . Material and assemblies shall comply with applicable code requirements.

   c. **Partitions in non all-gender restrooms**: Partitions shall be stainless steel, ceiling-hung with concealed hardware. Floor-and-ceiling anchored if ceiling-hung is not feasible.

   d. No partition gaps allowed at either side of the privacy door, between dividing panels, or at wall interfaces. For all-gender spaces, minimize gaps at ceiling or floor (½ inch max at ceiling, ¼–inch max at floor) and at any location where privacy may be compromised.

   e. For renovation projects where existing toilet compartments are retained that do not provide graffiti-resistant surfaces, provide a manufacturer-approved anti-graffiti coating or protective covering. Coordinate with Caltech PM and ensure the treatment does not void existing warranties.

4. **Installation Requirements:**
   - **a.** Add required blocking in wall or ceiling.
   - **b.** Install per manufacturer's instructions
5. **Field Control, Evaluation, and Commissioning:**
   - **a.** Inspect installation and verify work is complete and properly installed.

Section 10 26 00 – Wall and Door Protection

1. **Overview:**
   - **b.** Provide corner guards and chair rail of appropriate design in high traffic areas and utility corridors to protect walls.
2. **Performance Requirements:**
   - **a.** Quality Assurance
     - **1)** Mock-ups
     - **2)** Standards and certifications
   - **b.** Sustainability
   - **c.** Submittals
     - **1)** See Appendix II, Submittal Register
   - **d.** Warranties
     - **1)** See Appendix II, Submittal Register

3. **Product Requirements:**
   a. **Corner Guards**: Stainless steel, ASTM A 240/A 240M, Type 304. 6 feet default height; discuss with Caltech Planning, Design & Construction for special consideration/recommendation.
4. **Installation Requirements:**
   a. Install per manufacturer's instructions.
5. **Field Control, Evaluation, and Commissioning:**
   a. Inspect installation and verify work is complete and properly installed.

Section 10 28 13 – Toilet Accessories

1. **Overview:**
   a. Toilet accessories in public and private toilet rooms
   b. Paper towel dispensers in kitchens and laboratories
2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
   b. Sustainability
   c. Submittals
      1) See Appendix II, Submittal Register
   d. Warranties
      1) See Appendix II, Submittal Register
3. **Product Requirements:** Substitution and placement location of the following items require approval from Caltech Planning, Design & Construction and FOS Buildings and Grounds.
   a. **Paper Towel and Waste Units**: Dispense paper rolls and be ADA compliant.
      1) **Recommend**: Provide combination towel/waste units with a minimum of 18–gal waste capacity.
      Restroom: Bobrick models B–39619
      Lab with limited space: Bobrick Model B–2860.
   b. **Toilet Tissue Dispenser**: Capability to dispense multi-rolls.
      1) **Recommend**: Recessed seat-cover dispenser, sanitary napkin disposal, and toilet tissue dispenser (Bobrick B-35745 or B-4288)
   c. **Sanitary Dispensers**: Provide “free/no-cost” sanitary napkin and tampon dispensers in women’s and all-gender restrooms.
   d. **Sanitary Disposal Unit**: Women’s restrooms shall have in each stall a sanitary disposal unit.
      1) **Recommend**: Bobrick B270 (if tissue dispenser unit is not equipped with disposal unit).
   e. **Toilet Seat Covers**: Each toilet compartment and single toilet room shall have a seat cover dispenser unit with the capability of disposing half fold covers. No roll units allowed.
      1) **Recommend**: Bobrick B-4221 or B-221 (if tissue dispenser unit is not equipped with dispenser).
   f. **Soap Dispensers**: A ratio of one soap dispenser per every two sinks is required.
      1) **Recommend**: LumeCell dispenser (Rubbermaid Commercial Products), black or chrome finish.
   g. **Mirror**: Each lavatory counter shall have a mirror.
   h. **Trash Containers**: Each restroom shall have a trash container with a rigid plastic liner and lid (18-gal capacity) by exit door. Floor standing with dome top.
      1) **Recommend**: Bobrick B-2300.
   i. ADA-compliant paper roll towel dispenser in kitchens and laboratories
      1) **Recommend**: Bobrick B-2860, or Bobrick B2621 with towel mate accessory 262-130.
   j. Soap Dispensers in Kitchens:
      1) **Recommend**: Rubbermaid touch-free dispenser 1980827.

4. **Installation Requirements:**
   a. Install per manufacturer's recommendations
   b. Comply with applicable ANSI standards and current edition of Tile Council of North America TCNA Handbook for Ceramic, Glass, and Stone Tile Installation.
5. **Field Control, Evaluation, and Commissioning:**
   a. Inspect installation and verify work is complete and properly installed.

DIVISION 11 – EQUIPMENT

Equipment Sustainability Principles:

Energy modeling should be performed to support life-cycle cost evaluation. All large equipment including fume hoods, refrigerators, and other scientific equipment should maximize energy efficiency and performance to the greatest extent possible given project scope, budget, and schedule constraints. Placards containing building user guides promoting the AiM Facilities Service Request system, energy/water conservation, and proper waste practices shall be provided by the project contractor in coordination with the Caltech project manager and sustainability manager.

Section 11 13 00 – Loading Dock Equipment

1. **Overview:**
   - **a. Gates**: Loading docks shall be provided with a pair of swinging gates with drop rod anchors, unless specified otherwise.
2. **Performance Requirements:**
   - **b.** Quality Assurance
     - **1)** Mock-ups
     - **2) Standards and Certifications**: Verify that plastic products, including plastic components in assemblies, to be incorporated into the project are labeled in accordance with ASTM D1972. Where products are not labeled, provide product data indicating polymeric information in operation and maintenance manual.
   - **c.** Sustainability
   - **d.** Submittals
     - **1)** See Appendix II, Submittal Register
   - **e.** Warranties
     - **1)** See Appendix II, Submittal Register
3. **Product Requirements:**
   - **f. Dock Bumpers**: Molded, ozone-resistant rubber, nylon or polyester reinforced, minimum shore A durometer of 80, tensile strength of 950 to 1050 psi.
   - **g.** Bumpers
   - **h.** Levelers
   - **i.** Dock seals
4. **Installation Requirements**
   - **j.** Install per manufacturer's instructions.
5. **Field Control, Evaluation, and Commissioning:**
   - **a.** Inspect installation and verify work is complete and properly installed.

Section 11 20 00 – Institutional Equipment

1. **Equipment Selections:** Consult Caltech project manager regarding information specific to institutional equipment.

Section 11 30 00 – Residential Equipment

1. **Equipment Selections:** Consult Caltech project manager regarding information specific to residential equipment and appliances.

Section 11 52 00 – Audio-Visual Equipment

1. **Audio/Visual Equipment Accessories:** Provide ceiling projector mounts in conference rooms and required power and IT.

Section 11 53 00 – Laboratory Equipment

1. **Gas Cabinets:** Design professional to meet with Caltech Safety Office (Environmental Health & Safety) and the Fire Marshal, as applicable, to properly locate cabinets and determine maximum allowable quantities (MAQs). Cabinets must be UL listed and meet current California Fire Code and NFPA 30 requirement.
   a. Follow current California Fire Code requirements for toxic gases.
   b. Conform to FM Global recommendations.
2. **Flammable Safety Cabinets:** Design professional to meet with Caltech Safety Office (Environmental Health & Safety) to properly locate cabinets. Cabinets must be UL listed and meet current California Fire Code requirements.
   a. **Corrosive Cabinets:** Label "CORROSIVES" in conspicuous silk-screened lettering. Stick on decals are not acceptable.
      1) Cabinet finish and hardware shall be corrosion resistant and compatible with stored materials.
   b. **Flammable Cabinets:** Label "FLAMMABLE, KEEP FIRE AWAY" in conspicuous silk-screened lettering. Stick on decals are not acceptable.
   c. It is Caltech's preference for corrosive cabinets to have louvers in doors. Where louvers are provided, they shall not compromise the fire resistance rating or listing of the cabinet.
   d. Doors need to be self-closing with three-point latch.
   e. Flammable cabinets shall not be vented. Where venting is required by code, obtain approval from Caltech EH&S.
3. **Snorkels:** Local exhaust ventilation (e.g., "snorkels") may be used in cases where heat, particulate, or odor control is needed. These may not be used in place of fume hoods for exposure control. An assessment by EH&S is needed to determine if use is appropriate.

Section 11 53 13 – Laboratory Fume Hoods

1. Refer to **APPENDIX XXVIII – Fume Hood Selection Features** for additional considerations.
2. **General:**
   a. Summary
      1) Section Includes:
         i. Bench-top laboratory fume hoods.
         ii. Floor-mounted laboratory fume hoods.
         iii. Fume hood base cabinets.
         iv. Work tops within fume hoods.
         v. Laminar flow fume hoods
         vi. Water, laboratory, gas, and electrical service fittings in fume hoods.

b. Performance Requirements:

1) **Containment:** Provide fume hoods that comply with the following when tested according to ASHRAE 110 as modified below at a release rate of 4.0 liters per minute (LPM):
   i. **Sash:** Operating position while work is being performed in the chemical fume hood is a maximum of 18" opening for vertical rising sashes.
   ii. Sash setup position is defined as an opening greater than the operating position of 18" for loading materials with which to perform work. Work should not be performed in the setup position.
   iii. **Average Face Velocity:** 100 fpm with sashes fully open in operating position
   iv. **Face-Velocity Variation:** Factory tested not to exceed 20% of average face velocity.
   v. **Working Sash Position:** Fully open operating position at 18 inches for vertical rising sashes.
      a) Test hoods with horizontal sashes with maximum opening on one side, with maximum opening in the center, and with one opening at each side equal to half of maximum opening.
      b) Test hoods with combination sashes fully raised to 18", with maximum opening on one side, with maximum opening in the center, and with one opening at each side equal to half of maximum opening.
   vi. **As-Manufactured (AM) Rating:** AM 0.05 (0.05 ppm).
   vii. **As-Installed (AI) Rating:** AI 0.1 (0.1 ppm).
2) **Static-Pressure Loss:** Not more than 0.5-inch wc at 100-fpm face velocity when measured at four locations 90 degrees apart around the exhaust duct and at least three duct diameters downstream from duct collar.
3) **Structural Performance:** Provide fume hood components capable of withstanding the following loads without permanent deformation, excessive deflection, or binding of cabinet drawers and doors:
   i. **Chemical Fume Hoods:**
      a) **Work Tops:** 75 lb/ft.
      b) **Base Cabinets of Chemical Fume Hoods:** 75 lb/ft.
   ii. **Radioisotope Fume Hood Work Tops:** 200 lb/ft.
   iii. **Base Cabinets of Radioisotope Fume Hoods:** 75 lb/ft. within cabinets, 50 lb/ft. work top, 200 lb/ft. on work top, plus weight of hood.
4) **Seismic Performance:** Fume hoods, including attachments to other work, shall comply with code and withstand seismic forces determined in accordance with ASCE 7. Provide seismic anchorage and bracing as required by code.
5) **Product Standards:** Fume hoods shall comply with SEFA 1 (Scientific Equipment and Furniture Association), Laboratory Fume Hoods – Recommended Practices, and shall be listed and labeled in accordance with UL 1805.
6) **Safety Glass:** Products complying with testing requirements in 16 CFR 1201 for Category II materials.
   i. **Markings:** Permanently mark safety glass with certification label of Safety Glazing Certification Council or another certification agency acceptable to authorities having jurisdiction.
7) **Electrical Components, Devices, and Accessories:** Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
8) **Airflow Monitor:** Hoods shall be equipped with a quantitative airflow monitor that continuously indicates whether air is flowing into the exhaust system during operation.
   i. The quantitative airflow monitor shall measure either the exact rate of inward airflow or the relative amount of inward airflow. Examples of acceptable devices that measure the relative amount of inward airflow include diaphragm pressure gauges (airflow monitor).
   ii. The requirement for a quantitative airflow monitor may also be met by an airflow alarm system if the system provides an audible or visual alarm when the airflow decreases to less than 80 fpm.
   iii. Airflow monitoring devices shall be factory and field calibrated in accordance with manufacturer's recommendations.

9) **Acoustic performance:** Submit chemical fume hood's acoustical performance data measured by a certified acoustical test lab. Clearly indicate the sound power level for each octave band under normal operating condition at full sash opening.
   i. Chemical fume hoods without certified acoustical test data shall not be considered.
10) In accordance with UL 1805, fume hoods shall be supplied factory pre-piped and pre-wired to POC for mechanical and electrical trades.
   i. Hoods shall be pre-piped and pre-wired to top.
   ii. **DI water piping:** DI water piping in fume hood shall be 316L stainless steel tubing. Polypro piping is not acceptable.
11) **Fume Hood Location:** Fume hoods shall be located away from activities or facilities that produce air currents or turbulence.
   i. Locate away from high traffic areas, air supply diffusers, doors, and operable windows.
   ii. Fume hoods should not be located adjacent to a single means of access to an exit.
   iii. Recommendation is that hoods be located more than 10 feet from any door or doorway.
   iv. EH&S and the designated design professional shall jointly review hood locations during design to minimize cross drafts and traffic impacts.
12) New fume hoods are preferred to have ceiling enclosure that fills the space between top of the hood and ceiling, to provide a finished appearance. Confirm with Caltech PM on requirement for specific projects.
13) **ADA Fume Hoods:** Where ADA accessibility is required, consider side-approach fume hood configurations.
   i. Coordinate accessibility requirements with the project design professional and Caltech PM.

3. **Products:**
   a. Manufacturers
      1) **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
         i. Hamilton Laboratory Solutions
         ii. Kewaunee Scientific Corporation; Laboratory Products Group
         iii. Labconco Corporation
         iv. Mott Manufacturing
         v. Hanson Lab Solutions Inc.
         vi. Labconco
         vii. Earlab
         viii. Substitutions as allowed in writing by Caltech project manager.
   b. Fume Hood Ventilation
      1) **Constant-Volume Fume Hoods:**
         i. The type of bypass (i.e., open bypass vs. restricted bypass) shall be determined during design and programming phase after detailed analysis by the mechanical engineer.
         ii. Chemical fume hood shall readily be capable of operating at 60 fpm velocity without any modifications in order to accommodate expected lower future face velocity requirements.
         iii. Exhaust air static pressure at the hood shall be no less than the manufacturer's minimum requirement.
         iv. Provide packless or chemical rated sound attenuator as needed to attenuate excessive transmitted sound from the roof exhaust fan.
      2) **Variable-Air-Volume Fume Hoods:**
         i. **Variable-Air-Volume Fume Hood Control:** Provide variable air volume fume hoods as indicated on lab or architectural plans.
            a) Coordinate with work provided in Section 23 09 00 - Instrumentation and Controls for HVAC Systems
            b) Controls NIC for Fume Hood Manufacturer.

ii. Chemical fume hood operating in variable air volume (VAV) mode shall feature automatic sash closer and occupant proximity sensor to automatically close the sash when there are no occupants near the fume hood for a period of 10 minutes (adjustable) or longer.
iii. Automatic sash closer shall utilize optical sensor to prevent sash closure when there is an obstacle at the fume hood opening.
iv. Chemical fume hood shall readily be capable of operating at 60 fpm velocity without any modifications, to accommodate expected lower future face velocity requirements.
v. Exhaust air static pressure at the hood shall be no less than the manufacturer's minimum requirement.

3) **Base Cabinets and Base Cabinet Ventilation:**
i. Base cabinets serving acid and base storage shall be internally vented to the back of the exhaust baffle plenum.
ii. **Vacuum Pumps:** Base cabinets shall be internally vented to the back of the exhaust baffle plenum via a 1" O.D. polypropylene pipe. Provide a pilot lit toggle switch outside the base cabinet to energize and de-energize the vacuum pump. Provide dedicated power for vacuum pump in the base cabinet.
iii. Provide a cooling fan inside the vacuum pump base cabinet to maintain the temperature below 95˚F. Operation of the cooling fan shall be interlocked to the vacuum pump. Hot air shall be rejected to the room from the rear side of the base cabinet through the cooling fan opening. Provide provisions for make-up air, as required.
iv. Provide internal acoustical lining to attenuate vacuum pump noise and a thermostatically operated internal cooling fan to exhaust the heat being rejected by the vacuum pump.
v. Provide a pull-out roller tray at the bottom of vacuum pump base cabinet to accommodate maintenance.
vi. Solvent storage base cabinet shall be directly connected to the main exhaust duct above the fume hood collar via a manufacturer furnished 2" diameter stainless steel flexible duct and saddle connection.
vii. Provide base cabinets in finish matching fume hood exterior finish.
viii. Base cabinet doors shall be self-closing and self-latching.

4) **See** Appendix XXIII for additional fume hood and related exhaust memorandum of understanding (MOU).

4. Execution

a. Examination and Installation

1) Examine areas, with installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of fume hoods.
2) Proceed with installation only after unsatisfactory conditions have been corrected.
3) Install fume hoods according to shop drawings and manufacturer's written instructions.
i. Install level, plumb, and true; shim as required, using concealed shims, and securely anchor to building and adjacent laboratory casework.
ii. Securely attach access panels but provide for easy removal and secure reattachment.
iii. Where fume hoods abut other finished work, apply filler strips and scribe for accurate fit, with fasteners concealed where practical.
4) Comply with requirements in Section 12 35 53 - Laboratory Casework," for installing fume hood base cabinets, work tops, and sinks.
5) Comply with requirements in other divisions and sections for installing water and laboratory gas service fittings and electrical devices.
i. Install fittings according to shop drawings, installation requirements in SEFA 2.3, and manufacturer's written instructions. Set bases and flanges of sink and work top–mounted fittings in sealant recommended by manufacturer of sink or work top material. Securely anchor fittings to fume hoods unless otherwise indicated.

6) Field test installed fume hoods according to "Flow Visualization and Velocity Procedure" requirements in ASHRAE 110.
   i. Test all installed fume hoods, selected by architect, for each type of hood installed, according to ASHRAE 110 containment test procedures and as modified in "Performance Requirements" article. If any tested hood fails to meet performance requirements in the field test, notify Caltech PM and the architect.
7) Correct deficiencies identified during ASHRAE 110 field testing and verify compliance with performance requirements.
   i. Adjust fume hoods flow rate, hood exhaust fans, and the building's HVAC system, or replace hoods and make other corrections until tested hoods perform as specified.
   ii. After making corrections, retest fume hoods that failed to perform as specified.
8) Fume Hood Schedule:
   i. **Bench Top Fume Hood Type:**
      a) **Ventilation Type:** Constant volume or variable air volume, depending on HVAC design
      b) **ASHRAE 110 As-Manufactured (AM) Rating:** AM 0.05 (0.05 ppm)
      c) **ASHRAE 110 As-Installed (AI) Rating:** AI 0.1 (0.1 ppm)
      d) **Sash Configuration:**
         i) **Operation:** Combination sash consisting of two horizontal-sliding, bypassing sashes retained in a vertical-sliding, single-hung, top-hung frame
         ii) **Max. Opening Height for Setup:** 27 to 30 inches
         iii) **Max Opening Height for Working:** 18 inches
         iv) **Work Top:** Epoxy
         v) **Cup Sinks:** Polypropylene, 3-by-6-inch oval
         vi) **Service Fittings:** Provide the following with quick connect compression connections at valve body where indicated or required in accordance with UL 1805:
            I. **Water:** One or more rigid, gooseneck, remote-control, single-service faucet(s), and removable serrated outlet.
            II. Laboratory gas for air, gas (fuel gas), vacuum, or as shown. One or two flange-type fitting(s) with angled outlet and remote-control needle valve.
            III. **Electrical:** One duplex receptacle at both ends of hood, mounted on exterior front face of end pilaster.
            IV. Provide GFCI receptacles.
9) Provide and install a dedicated isolation valve for each utility serving each and every fume hood by plumbing contractor.
   i. One isolation valve is required per utility service per fume hood.
   ii. Grouping of isolation valves is not allowed.
   iii. Isolation valves to be provided and installed by the plumbing contractor or other installing subcontractor as per contract.

Section 11 53 13.15 Exhaust Hood

1. Refer to laboratory exhaust hood table below

2026 Laboratory Exhaust Hood V5.5

Section 11 53 13.30 Biosafety Cabinet

1. Location: BSCs shall be located away from activities or facilities that produce air currents or turbulence. Locate away from high traffic areas, air supply diffusers, doors, and operable windows. BSCs should not be located

adjacent to a single means of access to an exit. Recommendation is that BSCs be located more than 6 feet from any door or doorway and another directly facing BSC.

Section 11 81 29 – Facility Fall Protection Equipment

1. Roofs without parapets and guardrails shall be provided with the required fall protection. The system shall provide continuous protection for multiple users working at any height. Parapets that do not meet applicable code requirements for fall protection shall be supplemented with a permanent fall protection system.

Section 11 82 23 – Recycling Equipment

1. Each office shall have a minimum of one recycling container — Rubbermaid, Model 2956-06 (Blue color).
2. Laboratories shall have space for a minimum of one recycling container upon request from the laboratory occupants – Rubbermaid, Model FG354007 (blue color). Coordinate with the director of Building and Grounds and the manager for sustainability programs for guidance.
3. Each floor shall have space for a minimum of three recycling containers, or a recycling station, in or near a central, easy to access location such as a break room, kitchen, elevator, or other area with high occupant usage and visibility – Rubbermaid, Model FG354007 (blue color). Additional bins may be required per building requirements.
4. Each central copy room, print room, and/or mailroom shall have space for a recycling container for mixed paper — Rubbermaid, Model FG354007 (blue color).
5. Each station shall have a distinct lid for each recycling container — mixed paper, bottles and cans, and all others — Rubbermaid, Model 2692-88, 2703-88 and 1788372 (Blue Color). Coordinate with the director of Building and Grounds and the manager for sustainability programs for guidance.

DIVISION 12 – FURNISHINGS

Materials Sustainability Principles:

Use of products and materials with recycled content, environmental product declarations (EPDs), responsible sourcing documentations, and reduced embodied carbon should be prioritized when practical. Locally sourced and manufactured material should be prioritized where feasible. Non-virgin and recycled materials should be prioritized for applications including window shades, casework, storage cabinets, work surfaces, sinks, faucets, tables, chairs, and other furnishings. Overall, compliance with California Proposition 65 and minimization of environmental impact for the above listed materials are to be prioritized in all projects adhering to these design guidelines.

Section 12 24 00 – Window Shades

1. Roller Shades:

For all window shades, review with Caltech before final selections.

For exterior fenestration, provide roller shades; all shades should be manual with any deviation to be approved by PD&C architect. For renovation projects, consider existing building shade type and color for matching or coordinated exterior look.

Review with Caltech options of window shade systems and their integration with the façade or fenestration in order to select the most adequate approach per project and condition.

Design is to minimize unusable space between shade and envelope and minimize the likelihood of failure.

Prior to approval, and at project close-out: Provide Caltech with documentation in print, presentation, or video, that shows operating instructions and outlines any user practices that should be avoided or that have been found in the past to cause the shade system to fail.

Section 12 32 00 – Manufactured Wood Casework

1. **Overview:**
   a. **Custom Casework:** Wood veneer and plastic-laminate cabinets.
   b. **Kitchenettes**

2. **Performance Requirements:**
   a. Quality Assurance
      1) Mock-ups
      2) Standards and certifications
         i. Provide Woodwork Institute (WI)–certified compliance labels and certificates indicating that woodwork, including installation, comply with requirements of WI premium grade.
   b. Sustainability
      1) Provide interior architectural woodwork produced from wood obtained from forests certified by a Forest Stewardship Council (FSC)—accredited certification body to comply with FSC STD-01-001, FSC Principles and Criteria for Forest Stewardship.
      2) Comply with South Coast Air Quality Management District (SCAQMD) rules for VOC limits for installation adhesives and glues.
      3) Do not use adhesives that contain urea-formaldehyde.
   c. Submittals
      1) Woodwork Institute (WI) certified compliance labels.

2) Seismic performance compliance.
3) See Submittal Register, Appendix II

d. Warranties
1) See Submittal Register, Appendix II

3. **Product Requirements:**
a. Provide exterior-grade plywood, minimum 3/4 inch thick, core material at sinks and shelves. Provide plastic-laminate backer sheet, Grade BKL, on underside of countertop substrate.
b. Provide locks on cabinet drawers and doors where requested.
c. **Drawer Slides:** Side-mounted, full extension, zinc coated.
1) Accuride 3832 regular or easy close
i. Up to 100 lbs.
ii. Up to 36" wide
2) Accuride 4034 regular or easy close
i. Up to 150 lbs.
ii. Up to 42" wide
d. **Transparent and Paint Finishes** are to be approved by the Paint Shop.
1) Gemini conversion varnish for millwork. This type of treatment cannot be site-applied.
2) Treatment applied on-site is to be water-based, satin finished.
e. **Kitchenettes:** Coordinate requirements with Caltech project manager for kitchenette design.
1) Provide a minimum of 30 inches deep knee space for undercounter refrigerators and freezers. Coordinate mechanical and plumbing work to avoid conflicts with the placement of the undercounter equipment.
2) **Countertops:** Provide solid surface material countertops in kitchenettes. Plastic laminate countertops are not permitted.
i. Fabricate tops in one piece, as much as possible. Comply with solid surfacing material manufacturer's written recommendations for adhesives, sealers, fabrication, and finishing. Drill holes in countertops for fittings and accessories.
3) Cabinet/Casework: Particle board–based surfaces are not permitted in wet areas.

f. **Restroom:**

1) **Countertops:** Provide solid surface material countertops. Plastic laminate countertops are not permitted.
i. Fabricate tops in one piece, as much as possible. Comply with solid surfacing material manufacturer's written recommendations for adhesives, sealers, fabrication, and finishing.
2) Cabinet/Casework: Particle board–based surfaces are not permitted in wet areas.

4. **Installation Requirements:**
a. Do not deliver or install casework until building is enclosed, wet work is complete, and HVAC system is operating and maintaining temperature and relative humidity at occupancy levels during the remainder of the construction period.
b. All supply cabinets and bookcases are to be anchored to the wall and shelves shall have earthquake restraints to prevent items from falling.

5. **Field Control, Evaluation, and Commissioning:**
a. Inspect installation and verify work is complete and properly installed.

Section 12 35 53 – Laboratory Casework

1. **GENERAL**
   - **a.** SUMMARY
     - **1)** This section primarily specifies wood laboratory casework.
     - **2)** Metal laboratory casework is specified in Section 12 35 53.13.
     - **3)** Requirements in Part 1 and Part 3 of this section apply to both wood and metal casework unless noted otherwise.
     - **4)** **Section Includes:**
       - **i.** Wood Casework
       - **ii.** Table Frames
       - **iii.** Work Surfaces
       - **iv.** Sinks, drain outlets
       - **v.** Service fittings
       - **vi.** Accessory items specified herein, including under-cabinet and under-shelf task lighting systems where required.
     - **5)** **Related Sections**:
       - **i.** Section 09 65 00 Resilient Flooring for furnishing and installation of base molding.
       - **ii.** Section 11 53 13 Laboratory Fume Hoods
       - **iii.** Section 12 35 53.13 Metal Laboratory Casework
       - **iv.** Section 22 00 00 — Plumbing Systems for furnishing and installation of piping drain line, traps. Final connections and setting of sinks and fixtures.
       - **v.** Section 26 00 00 — Electrical Systems for furnishing and installation of electrical wiring, conduit and/or electrical items and final connections.
     - **6)** Laboratory casework shall be designed as an integrated system including casework, work surfaces, support framing, and utility distribution systems and accessories. Utility distribution may include service chases, overhead service carriers, ceiling service panels, vertical chase panels, and service drops (umbilicals), coordinated with all building systems.
     - **7)** Laboratory casework may include fixed casework, modular systems, or adaptable casework systems depending on project requirements.
   - **b.** SUBMITTALS
     - **1)** **Product Data**: Submit manufacturer's catalog for reference. Include cabinet dimensions, configurations, construction details, joint details, attachment details, and rough-in details as required.
       - **i.** No added urea-formaldehyde: Product data sheets stating no added urea-formaldehyde (NAUF) has been used in the manufacturing process as required by the State of California CARB compliance, as applicable.
       - **ii.** Provide documentation of structural performance and compliance with SEFA testing standards.
     - **2)** **Shop Drawings**:
       - **i.** Provide 3/16–inch scale plans and 3/8–inch elevations of furniture, cross sections, rough-in and anchor placements, tolerances, and clearances. Indicate relationship of units to windows, doors, surrounding walls, and other building components.
       - **ii.** Submit current engineered seismic anchorage details from a licensed structural engineer conforming to California Building Code for all casework, support structure and all equipment as required by trades involved.
       - **iii.** See submittal register, Appendix II.
       - **iv.** Indicate design loads for casework systems including work surfaces, cabinets, and shelving.
       - **v.** Indicate coordination with mechanical, electrical, and plumbing systems including routing of services within or adjacent to casework.

3) **Samples**: Two each, unless noted otherwise:
   i. Worktop: 4-by-4–inch sample of each material.
   ii. Finish: 3-by-5–inch sample of each available standard stain color with finish.
   iii. Hardware: Pulls, locks, hinges, and drawer slides.
   iv. Certified independent SEFA finish test results.
   v. One complete base cabinet, with specified hardware, standing height 24–inch–wide solid door / drawer combination or from an elevation shown on the drawings. This approved unit shall be used as part of the project.
4) **Mock-ups**: For new construction projects, provide coordinated mock-ups or review assemblies demonstrating integration of casework, service fittings, utilities, and accessories as required by the project.
5) **Product Certificates**:
   i. Woodwork Institute (WI) Certified Compliance Program certificates.
   ii. Forest Stewardship Council (FSC) chain of custody certificate from fabricator and installer if project is specified FSC.
   iii. SEFA compliance for structural integrity load testing and certified by an independent testing laboratory for drawer, door, base cabinets, and wall cabinet.

c. QUALITY ASSURANCE
1) **Quality Standard:** Wood casework shall be built to AWS premium grades, unless more stringent requirements are required by this specification.
2) **Environmental Compliance:** All composite panel products and adhesives used in the fabrication shall comply with the California Air Resources Board (CARB) provisions of 93120–93110.12, Title 17, California Code of Regulations for no added urea formaldehyde.
3) **Sustainability:** Design teams are encouraged to specify low-emitting materials compliant with SCAQMD requirements, FSC-certified wood products where applicable, and products with environmental product declarations (EPDs).
4) **Manufacturer's Qualifications:** Modern plant with proper tools, dies, fixtures, and skilled production staff to produce high-quality laboratory furniture and fume hoods, and shall meet the following minimum requirements:
   i. Minimum of 10 years' experience in the supply and installation of wood laboratory furniture and fume hoods.
   ii. Manufacturer must be a member in good standing of the Woodwork Institute.
   iii. Manufacturer shall demonstrate experience with wood, painted steel, and stainless steel laboratory casework systems of similar scale and complexity as required by project.
5) **Accessibility:** Laboratory casework and related furnishings shall comply with accessibility requirements where applicable.

d. PERFORMANCE REQUIREMENTS
1) **General:** Laboratory casework shall comply with SEFA 8 (baseline), SEFA 8M (additional for metal), and SEFA 10 (adaptable systems). In addition to SEFA compliance, laboratory casework shall meet the minimum structural performance requirements indicated in this guideline.
2) **Structural Performance:**
   i. Provide casework and support systems capable of supporting the following minimum loads without permanent deformation or functional impairment:
      a) Work surfaces and base cabinets:
         i) 600 pounds per linear foot (minimum)
      b) Wall-mounted cabinets:
         i) 300 pounds total load
      c) Shelving:

i) 40 pounds per linear foot minimum

d) Suspended or cantilevered casework:

i) 300 pounds per linear foot

e) Drawers:

i) 150 pounds minimum load capacity per drawer

f) Utility tables:

i) 300 pounds minimum total load capacity

3) **Deflection Limits:**
   - **i.** Maximum deflection shall not exceed L/180 of span.
   - **ii.** Maximum allowable deflection: 1/8 inch.
4) **Seismic Performance:**
   - **i.** Casework and support systems shall comply with California Building Code and ASCE 7 requirements.
   - **ii.** Provide engineered seismic anchorage and restraint calculations prepared and stamped by a licensed structural engineer.
5) **Operational Performance:**
   - **i.** Drawers and doors shall operate smoothly under full load.
   - **ii.** Hardware shall not deform or fail under repeated use.

e. DELIVERY, STORAGE AND HANDLING

1) **Delivery:** Schedule delivery so rooms are sufficiently complete that material can be installed immediately following delivery.
2) **Furniture and Work Surfaces:** Protect finished surfaces from soiling or damage during handling and installation.

f. FIELD CONDITIONS

1) **Do not deliver or install wood products until the following conditions are met:**
   - **i.** Windows and doors are installed, and the building is secure and weathertight.
   - **ii.** Ceiling, overhead ductwork, and lighting are installed.
   - **iii.** All painting is completed, and flooring is installed.
2) Interior building temperature to be between 65 and 80 degrees F and ambient relative humidity maintained between 25 and 55 percent prior to delivery, and during and after installation as required by the "Architectural Woodwork Standards" most current edition. Frequent and/or excessive changes in temperature and/or humidity levels during furniture installation, or once furniture is installed, must be avoided to prevent damage to materials.
3) Inspect installation and verify work is complete and properly installed.

g. WARRANTY

1) Manufacturer's standard form in which manufacturer agrees to repair or replace components of manufactured wood casework that fail in materials or workmanship within specified warranty period.
   - **i.** Failures include, but are not limited to, the following:
     - **a)** Delamination of components or other failures of glue bond.
     - **b)** Warping of components.
     - **c)** Failure of operation hardware.
     - **d)** Deterioration of finishes.
   - **ii.** Warranty Period: five years from date of substantial completion.
2) Submit sample copy of warranty with bid.
3) See submittal register, Appendix II.

2. PRODUCTS

a. MANUFACTURER, GENERAL

1) Design, materials, construction, and finish of furniture as specified represent the minimum acceptable standard of quality for wood laboratory furniture.

2) Manufacturers proposing furniture different from that specified must submit, at least 10 days prior to bid, documentation as required by contract documents to indicate an equal or better offering. A written approval by Caltech and design professional representative in addendum form prior to bid date is required to submit a bid.

3) Manufacturers shall demonstrate experience with both fixed and adaptable laboratory casework systems where required by the project. Laboratory casework systems may include wood, painted steel, stainless steel, or hybrid systems. Manufacturers shall demonstrate experience with the proposed system type.

b. WOOD CASEWORK MATERIALS

1) Laboratory casework materials shall be selected based on durability, chemical resistance, maintenance, and laboratory program requirements. Materials may include wood, steel, stainless steel, or other systems as appropriate.

2) **Definition of Cabinet Components by Surface Visibility**:

i. Exposed surfaces:

a) All surfaces visible when drawers and solid doors are closed including knee spaces.

b) Surfaces visible behind clear glass doors.

c) Interior surfaces of open units.

d) Bottoms of cabinets 42 inches or more above finished floor.

e) Tops of cabinets less than 80 inches above finished floor or are visible from an upper floor or staircase after installation.

f) Visible edges of cabinet body members.

g) Surfaces visible when fixed appliances are installed.

h) All four sides, edges of shelving in both cabinets and open shelving on walls or on tube steel frames.

ii. Semi-exposed surfaces:

a) Surfaces visible when doors or drawers are open.

b) Bottoms of cabinets 24 to 32 inches above finished floor.

iii. Concealed surfaces:

a) Surfaces not normally visible after installation. Note exceptions: specifically, finished ends.

b) Bottoms of cabinets less than 23 inches above finished floors.

c) Tops of cabinets over 80 inches above finished floor that are not visible from an upper level.

d) Stretchers, nailers, blocking, and components concealed by drawers.

3) **Hardwood**:

i. Hardwood lumber, free of defects. All lumber kiln dried to uniform moisture content of 6 to 8 percent.

a) Exposed Material: Hard White Maple compatible in color and grain.

b) Semi-Exposed Material: Select hardwood.

c) Concealed Material: Sound hardwood of species suitable for the intended purpose.

4) **Plywood Panel Product**:

i. Cores:

a) 7–ply minimum, 3/4–inch thick or 9–ply minimum, 1–inch-thick veneer core plywood with cross and face plies bonded with type II water resistant glue. Panels used for exposed surfaces must have cores using cross bands providing a uniform finish surface. Cores using wood outer cross bands that will telegraph through the exposed veneer are not acceptable.

b) Particleboard: Grade M–2, 45 lb. density. Use only for door and drawer front panels. Particleboard used for other cabinet components is not acceptable.

c) Pullboard Fronts: Veneered particleboard core to match appearance of doors drawer heads. Solid lumber is not allowed.

ii. Face Veneers: White (Grade A) Maple.

a) Option: Per Project Specifications. Red Oak, Cherry or Bamboo may be used.

i) To be considered a responsive bidder, manufacturer must be able to demonstrate they have the capability and experience to be able to provide any or all versions (sometimes different veneers may be specified on same Project).

b) Exposed surfaces shall be plain sliced select hard White Maple, vertical match (no heartwood). Grade A Book matched, running match within a panel.

c) Semi-exposed surfaces shall be plain sliced select hard White Maple (no heartwood) Grade A.

d) Concealed: Hardwood, manufacturer's option.

5) Hardboard: Wood fibers and natural resin binders formed under heat and pressure.

6) Glass shall be tempered glass, nominal ¼–inch in all locations, except for glass splash guard which shall be ½–inch in thickness with stainless steel U channels.

7) Glue: Laminating: Type II water resistant.

8) Edge-banding: 3 mm hardwood on edges of doors, radius, and drawer fronts. 3 mm on exposed edges of base, wall upper, and tall cabinets, and 3mm on exposed and all four edges of shelves. The bottom edges of wall cabinets shall be edge banded. The top edges of wall and tall cabinets defined as exposed shall be edge banded.

9) Finish shall be applied utilizing a mechanized flat line finish system for consistent application and even surface. Exposed and semi-exposed surfaces to have a highly chemical resistant SEFA finish and must contain a built in UV blocker. Stain if required. A minimum of six color choices shall be available. Custom stain must be available at no additional cost. Finish must have no or low-VOCs as required by local code requirements. Sample or/and cut sheet to be provided to Caltech project manager for approval.

c. WOOD CASEWORK FABRICATION

1) Door and Drawer Design:

i. Flush overlay:

a) flush overlay design, slight radius edge with 1/8–inch reveals, vertical and horizontal between doors, doors and drawers, and doors to side of carcass of cabinet. The reveal from the vertical edge of doors and drawers to the vertical cabinet side / ends shall be 1/16 inch providing a nominal 1/8–inch reveal where adjacent cabinets abut.

b) The reveal between doors and drawers and the top of base cabinet shall be 1/4 inch. The reveal between the doors and drawers and the bottom of the base cabinet shall be 1/8 inch. The reveal between doors and the top and bottom of wall and tall cabinet shall be 1/8 inch.

ii. Casework shall be built to standards set forth in AWS, current edition, for premium grade unless more stringent requirements have been specified here.

iii. Standard Grain Pattern

a) End panels: Vertical

b) Shelving: The grain shall run with the width (left to right) of the shelf

c) Bottoms and tops of all units: The grain shall run with the width (left to right) of the unit

d) Aprons and table frames: Horizontal

e) Knee space panels: Vertical

f) Finished backs: Vertical

iv. Grain pattern on cabinet fronts shall be vertical matched grain. Continuous vertical grain match on door and drawer fronts of individual cabinets.

a) Cabinet end panels exposed to view after installation must have finished ends. All panels not exposed to view after installation will be as listed under “concealed” surfaces, and may be unfinished, depending on project requirements.

b) All base and wall cabinets to have all finished grade veneer ends, regardless of whether they are exposed to view after cabinets are installed. Clear coat sealants on exposed veneer after installation are not acceptable.

c) If finished ends are intentionally omitted on cabinets not exposed to view after Installation, it shall be identified and approved by Caltech project manager. Otherwise, provide finished ends on all cabinets.

d) Cabinets to be rigid, modular in design, self-supporting for use in an assembly, or as a single stand-alone unit. Suspended units are manufactured with finished end both sides, without subbase; this also includes finished backs and finished bottoms, as project required.

v. Flush Interiors: Surface mounted bottoms and offsets caused by front face frames, which interfere with ease of cleaning, are not acceptable.

vi. Joinery: 32 mm doweled joinery system glued, clamped, and screwed. Dowels are to be hardwood, laterally fluted with chamfered ends and a minimum diameter of 8 mm. Spacing of dowels shall meet AWS.

a) Furniture height is to be within plus or minus 1/32 inch from what is shown on the drawings. The cabinet width is to be plus or minus 1/16 inch. The cabinet depth shall not be less than 24 inches deep from the face of the door to the back of the cabinet unless specifically shown otherwise. Cabinet shall be built less than 1 inch from outer door head height. Manufacturer’s standards are not acceptable unless they are able to build their cabinets to meet these dimension requirements. Any deviation from the standard shall be submitted to Caltech project manager for review and approval.

b) Drawer Body Sides: Joined by doweling with 5mm fluted dowels, 32mm on center. Cabinet box joined by using 8mm fluted dowels on cabinet box construction. Dovetail joinery is not acceptable.

c) Bottom: Nominal 1/4–inch thick for drawers up to 24 inches wide. Drawers over 30 inches wide shall have 1/2–inch-thick bottom, inset into all four sides of drawer box and sealed with hot melt glue around entire drawer bottom perimeter. Staples are not acceptable. Bottom material to be white vinyl clad MDF board with finished surfaces on both sides.

d) Door and Drawer Front Construction: 3–ply, 3/4–inch thick MDF (medium density fiberboard) core plywood with 3 mm matching species wood-banding on all edges. Reveal and regular edge panels are not permitted in laboratories.

e) Fillers, Knee Space Panels, Scribes, etc.: Same species and grade as adjacent exposed surfaces. 3/4–inch-thick, 7–ply minimum veneer core plywood as required to match the same stain and finish.

i) Knee Space Panels: Three-piece units that require 6–inch top rail (with cutouts as shown; cutouts to be done in factory or by casework vendor on site) and 4–inch bottom rail, along with a removable knee space panel.

ii) Data and electrical where occurs are cut into top 6–inch rail at factory.

iii) Student workstations knee space:

1. Provide factory cut for data 4 inches to left of knee space centerline to center of cutout.
2. Provide factory cut for electrical 4 inches to right of knee space centerline to center of cutout.

iv) Standing-height knee space panels:

1. Provide factory cut for electrical at centerline of panel in top 6–inch-high rail.

2. Support brackets at workstations in lab and office to be placed outside of the knee space, at edges of workstation space.

f) Pull Boards:

i) 1–inch-thick M2 particleboard with balanced high pressure chemical resistant laminated top and bottom with GP28.

ii) Front construction shall match drawer front construction, with reveals, hardwood match or vertical match veneer grain as specified for doors and drawer fronts.

iii) Pull boards require drawer pulls to match door and drawer pulls.

iv) Pull board face to be minimum 2–5/8 inches high for hardware clearance. Solid lumber components are not permitted.

v) Pull board sides to be edge-banded on sides and back with 0.018–inch-thick PVC.

vi) Pull board top: Horizontal grade plastic laminate, color: black or grey. Chemically resistant.

vii) Pull board bottom: Horizontal grade plastic laminate, color: white. Chemically resistant.

viii) Suspension shall be Accuride 3832 full extension, 100 lb., zinc-plated ball-bearing slides. Grade 1 slides are also acceptable if compliant with AWS.

vii. Upper Wall Shelves and Tall Cases:

a) Shall be manufactured with appropriate materials and joinery methods as specified for base unit except as noted below.

b) Tops: 1–inch thick, 7–ply minimum veneer core plywood with 3 mm matching species banding on front edge.

c) Bottom of Wall Upper and Tall Cases: 1–inch thick, 7–ply minimum veneer core plywood with 3 mm matching species banding on front edge.

d) Exposed Backs: 1/4–inch thick veneered MDF plywood. Back to be dado fully captive into sides, top, and bottom (Melamine printed veneers are not acceptable).

e) Semi-exposed backs shall be 1/4–inch thick veneered MDF plywood with backs recessed 3/4–inch and set into top, bottom, and ends. (Melamine printed veneers are not acceptable).

f) Shelves, fixed and adjustable: 1–inch thick, 9–ply minimum veneer core plywood: 3 mm matching species banded on all four edges of the shelf, front, sides, and back. Adjustable on 32 mm centers. The center shelf on a tall cabinet shall be fixed, nonadjustable, full depth.

g) At all open wall cabinets, shelf support holes must be drilled to within two to three inches of bottom of cabinet to accommodate placement of shelving to within two to three inches of bottom of cabinet.

h) Door construction shall be 3–ply, 3/4–inch-thick particleboard core plywood with 3 mm matching species banding on all four edges.

i) Tall Cabinet Doors: All tall cabinets to have 4 doors for any cabinet wider than 24 inches. For cabinets less than 24 inches wide, 2 doors, upper and lower, are required, and shall be split doors, with fixed structural rail in the middle flush with cabinet carcass. This is for all door styles, hinged or sliding.

j) Framed Glass Doors: Solid hardwood, stile and rail-style doors, ¾–inch by 2–1/4–inch frame stock with radius edges machined to accept glass, mitered joints, extruded vinyl retaining molding at interior side of door to allow glass to be replaced without tools. Mitered joints using exposed butterfly or bowtie fasteners and butt joints are not acceptable.

k) All upper wall cabinets to be secured to backing or studs.

viii. Hardware:

a) General: Hardware shall be corrosion-resistant and suitable for laboratory environments. Exposed hardware shall be stainless steel unless otherwise approved by Caltech PM.

b) Drawer suspension, except on file drawer, shall be full extension, ball bearing roller, 100 lb. dynamic load, zinc plated Accuride 3832. Side-mounted ball bearing, grade 1 also acceptable if compliant with AWS.
  i) File Drawers: Suspension shall be full extension, ball bearing roller, 150 lb. dynamic load, zinc plated. Accuride 3034. Side-mounted ball bearing, grade 1, also acceptable if compliant with AWS.
  ii) File drawer to have built-in Pendaflex file hanging system with rails oriented front to back, not in a lateral file arrangement. In certain cases, lateral files may be called for specifically, but the standard is for files to be set up in a front-to-back configuration. Caltech to specify if file drawers require front pocket 6 inches deep at file drawers.

c) Drawer and hinged door pull shall be stainless steel 96 mm wire.

d) Sliding doors will require a recessed stainless steel door handle —Sugatsune OP–150 recessed stainless-steel pull.

e) All pulls are mounted horizontally on drawers and vertically on doors, or as specified. All pull spacing must have 2” equidistant spacing from both the top and side face of both drawer and door units.

f) Hinges: Notch door to attain proper flush overlay reveal tolerances:
  i) 5–knuckle, stainless steel, institutional style, hospital tipped. Provide two hinges for doors up to 48 inches high: three hinges for doors over 48 inches high. Rockford Process 376, stainless steel.
  ii) Provide two hinges for doors up to 36 inches, three hinges for doors over 36 inches high, and additional hinges as required to comply with AWS and hinge manufacturer’s recommendations.

g) Shelf support clips shall be corrosion-resistant and rated for a minimum 200 lb evenly distributed load for 1–inch-thick shelving as part of the overall shelving system performance in accordance with SEFA requirements.

h) Door catches shall be:
  i) Adjustable, spring actuated nylon roller.
  ii) Elbow catch
  iii) Magnetic locks acceptable only on tall cabinets

i) Wall and base cabinet door catches when locks are required shall be elbow catches. Magnetic lock is not accepted unless approved by Caltech PM.

j) Locks where indicated on drawings shall be 5–pin tumbler bolt for grand master key system, and from the following manufactures:
  i) National Lock
  ii) CompX Security
  iii) Olympus Lock

k) Confirm with Caltech PM on keying on all projects.

l) Framed glass sliding door track shall be Hafele EKU-CLIPPO 15 SH in front. No substitutions. As a deductive alternate a plastic version of sliding hardware may be substituted in advance and must be approved by Caltech PM 10 days prior to bid, otherwise the Hafele style as stated above is the standard sliding door hardware for all sliding doors.

m) Tall cabinets to have stainless steel chain stops at doors adjacent to wall or protruding countertop corner

n) Casters:
  i) Caster selection shall be based on project-specific program needs and intended use, including but not limited to equipment-bearing furnishings, routine mobility, fixed leveling

requirements, and locking requirements. The design team or contractor shall confirm the intended use with the Caltech PM and recommend the appropriate caster type, load capacity, braking, leveling, and attachment requirements in the basis of design for Caltech review and approval.

ii) Caster load ratings shall be based on the fully loaded cabinet weight including contents and imposed operational loads.

I. With Brake: Load capacity as required by approved basis of design and intended use. Swivel caster dimensions and wheel materials shall be appropriate for the intended application and anticipated loading conditions.

a.Color: Grey or black.

II. Without Brake: Load capacity as required by approved basis of design and intended use. Swivel caster dimensions and wheel materials shall be appropriate for the intended application and anticipated loading conditions.

a.Color: Grey or Black.

o) Mobile Cabinet Anti-Tip and Stability Requirements

i) Hafele Anti-Tip System

ii) Provide counterbalance weights, ballast, or other anti-tip protection appropriate for cabinet size, drawer configuration, and anticipated loading conditions.

iii) Counterbalance systems and anti-tip devices shall be securely attached to cabinet structure and designed to prevent tipping during normal operation and movement.

p) Plastic Grommets: Provide grommets at desk and workstation locations as required, matching adjacent work surface finishes.

ix. Utility Integration: Casework shall be designed to accommodate plumbing, electrical, and specialty gas services. Provide accessible routing of service lines and allow for future modification without requiring demolition of casework.

a) Provide utility-space framing, filler panels, and closure panels as required to enclose and support services located behind, between, or adjacent to casework.

i) Provide removable access panels where required for maintenance of services.

ii) Provide filler panels at walls, ends of runs, and between cabinets for a complete installation.

iii) Coordinate with fume hoods, overhead service carriers, and laboratory equipment.

d. WOOD FINISH TESTING

1) Chemically Resistant Finish: All wood laboratory products shall utilize an environmentally friendly, laboratory grade finish. UV resistant, clear natural finish shall be applied in mechanized flat line finish system for even application. Only highly chemically resistant low or no VOC finishes that pass SEFA 8 recommended practices for chemical and durability resistance will be acceptable. A letter from a third-party testing agency, verifying independent test results, shall be submitted to the Caltech PM as part of the submittal process.

2) All testing to be done on plain sliced oak and / or plain sliced maple panels regardless of veneer species specified. High-performance chemical resistant SEFA 8 finish.

i. Chemical resistance test procedure: Follow SEFA 8 recommended practices for chemical resistant testing and evaluations. In addition, finished panels shall also be tested vertically during exposure to the test chemicals. Chemical concentrations shall be adjusted by the weight method. Ambient temperature and chemical temperature shall be 65 degrees F to 72 degrees F. At the end of the test period, the surface shall be washed with detergent and warm water and blotted dry. After 24 hours, the test surface shall be scrubbed with a damp paper towel and dried with paper towels, then evaluated.

a) Horizontal test: Apply five drops of the acid, base, or salt substance to correspondingly numbered areas of the surface to be tested. Position a 1–inch diameter watch glass in the liquid, convex side

downward. Solvents shall be applied by saturating a 1–inch ball of cotton, then covering with an inverted two-oz.-wide mouth bottle. Test duration shall be one hour.

b) **Vertical test:** The test surface shall be marked to indicate divisions: 12 inches high, 3/4–inch-wide and numbered to identify the chemicals. Five drops of each substance shall be applied to its respective numbered area in a vertical track pattern to prevent crossover. Test duration shall be two hours.

c) **Ratings**:

i) **No effect:** Indicates no effect in gloss or color.

ii) **Excellent:** Indicates slight change in gloss or color.

iii) **Good:** Indicates slight surface etching or discoloration.

d) **Test results:** Minimum requirements shall include no more than four individual chemical test results receiving a level 3 rating per SEFA standards. Third party test results are to be provided upon Caltech's request.

e. TABLE FRAME AND FREE-STANDING FIXED HEIGHT TABLES

1) **Perimeter Table Frame Rails:** 3/4 inch by 4–1/2 inches at sitting height or standing height tables, either hardwood or 7–ply minimum veneer core plywood with attached steel corner braces, grooved and screwed into both rails at each corner. Maple, grade A, to match casework.
2) **Reinforcing Cross Rails:** 3/4–inch thick, 7–ply minimum veneer core plywood, doweled and glued and pinned into front and back rails, at intervals not more than 33 inches on center in tables.
3) **Separate Cross Rails:** 3/4 inch by 4–5/16 inches hardwood or 7–ply minimum veneer core plywood with attached steel brackets at both ends.
4) **Legs:** 2 inches by 2 inches, same species, with 3/8–inch #16 x 3–1/2–inch hanger bolt inserted 1–3/4 inches into leg and fastened to perimeter rail corner brace. Provide steel levelers under each leg.
5) **Leg Rails (if required):** 1–1/4 inch by 2–1/2-inch hardwood mortised into legs and secured with 3/8–inch #16 x 5–inch stove bolt.
6) **Leg Shoes:** Black rubber or vinyl with provision for floor clip.

f. MOBILE CABINETS

1) **Design:** Overlay design shall be the same as specified under furniture design.
2) Cabinet sides, doors, and drawers will be constructed the same as base units.
3) Cabinet backs will be considered exposed. The backs shall be 3/4–inch thick doweled into the cabinet sides, top, and bottom and inset a nominal 2 mm.
4) The cabinet bottom shall be 3/4–inch thick with a 1/4–inch Europly bottom support extending 1/2–inch beyond the cabinet sides, front, and back.
5) The cabinet top shall be 11 3/4–inch thick and be a balanced construction with HGS horizontal grade laminate, color black or grey. Plastic laminate shall be chemically resistant type or epoxy resin as determined by the project requirements.
   i. The top shall be doweled into the cabinet sides and back, and inset a nominal 2 mm.
6) The casters specified under hardware shall be carriage bolted using a radius head at the inside of the cabinet. The lock nut is to be on the caster side. Hafele 637.67.910 levelers are also acceptable for mobile casters.
7) Caster attachment and structural performance:
   i. Provide reinforced mounting plates or structural reinforcement at caster attachment locations. Casters shall be through-bolted to cabinet structure and designed to support imposed static and dynamic loads without deformation, fastener pullout, instability, or failure of cabinet components.
   ii. Mobile cabinets shall remain stable and operational under full design load during movement and use.
8) The drawer hardware will be provided with anti-tip Hafele as specified in Hardware section of this specification or approved equal. Each cabinet will be provided with an internal counterbalance.

9) **Anti-Tip:** Provide counterbalance or anti-tip protection sized appropriately for cabinet dimensions, drawer configuration, and anticipated loading conditions. Counterbalance weight to be concealed on combination and on door units. Weight can be installed either at the back of the interior or underside of the cabinet bottom at the rear of the cabinet. Counterbalance weight to be 1/4–inch or 1/2–inch-thick steel depending on location and cabinet size or configuration.

g. TUBE STEEL FRAMES AND WALL STANDARDS

1) Adjustable shelves, wall cabinets, and pegboards mounted above peninsula or island benches shall be mounted to a welded double-sided, twin tracked stud assembly. Assembly shall be fabricated of 14 gauge, fully welded with welds concealed, steel tube with slots laser cut into uprights and be coated with an epoxy powder coat. Slotted island steel tube posts and matching wall standards shall have a fully compatible slot pattern.
   i. This will allow shelves amid brackets to be interchangeable between walls and island assemblies. Adjustable shelves, wall cabinets, and pegboards shall be furnished with integral mounting brackets or clips to meet design load.
2) Brackets / shelves are to run to outside slots of double tracked standards. Whether it is a wall standard or island upright, the brackets should fit in the outermost slot, to maximize the width of shelf. Therefore, installers can use inner slot on wall standards to install fasteners as required by job conditions. Notify Caltech PM if toggle bolts are used.
3) Middle and bottom reagent rack shelf brackets to be bookend style. As a standard, refer to drawings or design, as some job conditions dictate fixed (non-adjustable) bottom shelf. The top shelf to be under-mount or blade style. Note shelf depths and configurations will vary from job to job and must be indicated prior to bid as to what style (bookend or under-mount) can be provided, as the style will dictate other trades, specifically the layout and selection of task lights, as well as the design and selection of wire mold that has to fit under shelf bracket. Casework installer is responsible for assisting in coordination of design and layout (with Caltech input) to determine which style works best for each lab style.
4) **Plastic Laminate Shelf Construction:** All shelves on wall standards or on island assemblies will be made from 1–inch-thick particleboard core with chemical resistant tops and bottoms, with 3 mm maple (or matching species) edge bands, or as job requires. Note some shelves may only require 3 mm PVC edge bands, for non-lab or general storage areas. In addition, if due to spacing requirements and length of shelving, some shelves must be longer than 36 inches, plywood core shelving will be required to alleviate deflection, depending on job-by-job loading requirements. Check with Caltech PM before bidding to determine which core is a suitable material as required.
5) Shelves that mount on tube steel island assemblies will need detailed notching at corner of each shelf. Where shelf butts up to vertical tube steel post, this will require each shelf to have rear radius notches sprayed or applied with factory sealant to protect the exposed portion of notch that is not covered with edge banding material. Square or rectangular cutouts are not acceptable, and tolerances must be less than 1/16 inch at each radius notch, where it butts up to radius of tube steel upright.
6) **Seismic Rod and Turrets:** Stainless steel turrets 3/4–inch diameter by 2 inches high with 9/16–inch hole to accommodate 1/4–inch diameter stainless steel rods. Design turret spacing so no rod goes more than 24 inches unsupported, or without turret or attaching to end bracket. Basis of bid is for rods to be cut to match width of shelf, then add 1/16 inch to allow shelf to fit into brackets with 1/32–inch space between shelf edges and shelf bracket. Tight fit of shelf edges to shelf brackets is the intent.
7) Rod ends are to be drilled & threaded to allow direct attachment to bookend brackets, each also drilled to accommodate the screw attachment to the rod ends. In the event bookend brackets are not used but under-mount blade style shelf brackets are used, then rods and turret will go all the way around perimeter of shelf on all four sides to provide a seismic lip on all four sides of shelf includes end post turrets, pass through turrets, 90–degree turrets etc. All rods and turrets to be stainless steel.

8) Continuous tube steel horizontal service trough 4 by 6 inches (verify size; some may only be 4 by 4 inches) due to shelf design is required on all tube steel frames. Size is 4 by 6 inches. 1/8–inch-thick tube steel and painted to match. The service trough must have a separate removable top, which allows plumbing and electrical access, and is flush to allow shelf placement over trough. In addition, longer runs of trough require a male and female coupling point, to allow uninterrupted access from one end to the other. This way either end can serve as a main pipe drop point of connection. Trough is to be either drilled at factory for service fixture drops or drilled in the field by casework installer, as required.
9) Feet and mounting brackets for steel tube uprights to be designed so that they do not interfere with cabinet placement, so cabinet can be set adjacent to posts, and so that a hard plate steel connection can be made from back of cabinet to post upright. To ensure stability of post, this can be done by using a 14–gauge steel unistrut or other steel connection piece.
10) All tube steel island posts (vertical and horizontal) will be 2–inch by 2–inch. 1/8–inch-thick steel frames, bolted to floor with minimum of four 48 inch by 3/8–inch concrete anchors, drilled into concrete and designed to not interfere with cabinet placement.
11) Design tube steel and posts to withstand lateral loads and vibration, per job loading requirements. Provide structural calculations from licensed structural engineers as required. Casework installer to make any and all changes to design and fabrication if calculations are required and design (as shown) does not meet the structural engineering requirements. This rework-redesign is to be done at no charge to Caltech.
12) All overhead service carrier shall include a minimum of ¾–inch epoxy resin top (or approved equal) including a dual-stacked downward facing unistrut (or approved equal) to suspend monitors or equipment. All finishes with unistrut to have a minimum of powder-coated finishes or approved equal. Single shelf service carrier to have a load capacity of minimum 250 lbs.; double shelves to have a minimum 500 lbs. load capacity.

h. WORK SURFACES AND SINK

1) Epoxy Resin Work Surface:
   i. **Manufacturer:** Durcon Incorporated or approved equal.
   ii. **Materials and fabrication**:
      a) **General:** Material shall be a monolithic, filled epoxy resin product and shall consist of a polymerized cast resin material formulated to provide a work surface with high chemical resistance characteristics. The combination of epoxy resin and asbestos-free inert materials shall be oven cured in molds to obtain maximum chemical resistance, then removed from the molds and oven tempered to achieve maximum physical strength and stability. Surfaces shall have a uniform low-sheen surface, and the finished material shall be extremely hard and resistant to scratches and abrasion.
      b) Thickness shall be 1–inch-thick minimum.
      c) **Edges and corners:** Exposed work surface edges and corners, except as indicated, shall be furnished with 1/8–inch machined top edge with blended radius.
      d) **Surface:** Work surfaces shall be furnished as:
         i) Flat at all locations excepted sinks.
         ii) ¼–inch raised marine edge at sink locations. Coordinate marine edges at sinks with Caltech.
      e) Backsplashes shall be supplied loose for field application in the same material and thickness as countertops. Curbs as installed shall be 4 inches high, unless otherwise indicated on drawings. Curbs will be bonded to the countertops at the jobsite. Include top mounted end curb where work surfaces abut walls, fume hoods, and locations detailed on drawings.
      f) **Color:** Black onyx or grey; grey recommended.
      g) **Warpage:** Check work surface for warpage before fabrication. Measure in unrestrained condition. Work surface will be accepted for use if there is no gap exceeding 1/16 inch in a 36–inch span.

h) **Fabrication:** Provide in longest practical lengths. All joints shall be bonded with a highly chemical and corrosion resistant epoxy grout. Provide 1/8–inch drip groove on underside of exposed edges set back 1/2 inch from edge at all sink areas and where shown on drawings. All exposed edges to be molded or finished.

i) **Thickness tolerances:** Each corner of top shall not deviate more than plus or minus 1/16 inch from nominal.

j) **Size tolerances:** Length, plus or minus 1/8 inch. Width, plus or minus 1/16 inch.

iii. **Squareness:** Compare the diagonal corner-to-corner measurements across the width of each work surface. The diagonal measurements must be within 1/16 inch.

iv. **Penetrations:** Location of cutouts and drillings: plus or minus 1/8 inch. Sizes of cutout and drillings: plus or minus 1/16 inch. All penetrations to be coordinated with Caltech PM.

v. Trespa work surface can be used in lieu of epoxy resin work surface in certain labs. Coordinate with Caltech PM on use of Trespa work surface and specify Trespa Toplab Plus (25mm) in black or grey color as typical unless noted otherwise.

2) **Material Properties:** Provide independent testing laboratory report certifying that the epoxy work surface meets or exceeds the following test criteria:

i. **Chemical resistance**:

a) **Test methods**:

i) **Volatile chemicals (organic solvents):** A cotton ball, saturated with the test chemical reagent is placed in a one-oz. bottle (10 x 75 mm test tube or similar container) with a reservoir of liquid above the ball. The container is on the test material for a period of 24 hours at a standard temperature of 23 degrees C plus or minus 2 degrees.

ii) **Non-volatile chemicals:** Five drops (1/4 cc) of the test chemical are placed on the test material surface. The chemical is covered with a 25mm watch glass for a period of no less than 24 hours at a standard temperature of 23 degrees C plus or minus 2 degrees.

b) **Evaluation ratings:** After 24-hour exposure, surfaces are washed with water, then a detergent solution, finally with naphtha, then rinsed with distilled water and dried with a cloth. Change in surface finish and function shall be described by the following ratings:

i. **No Effect (1):** No detectable change in the material surface.

ii. **Excellent (2):** Slight detectable change in color or gloss, but no change to the function or life of the work surface material.

iii. **Good (3):** Clearly discernible change in color or gloss, but no significant impairment of surface life or function.

iv. **Fair (4):** Objectionable change in appearance due to surface discoloration or etch, possibly resulting in deterioration of function over an extended period.

v. **Failure (5):** Pitting, cratering, or erosion of work surface material: obvious significant deterioration.

c) Minimum acceptable test results shall be equal to or better than the following rating:

CHEMICAL	Minimum Acceptable Results	CHEMICAL	Minimum Acceptable Results
Inorganic Acids — Corrosive	4	Ethyl Acetate	1
Organic Solvent	1	Sulfuric Acid 96%	1
Chromic Acid 40%	2	Ethyl Alcohol 95%	1
Acetone	1	Organic Acids — Corrosive	1

CHEMICAL	Minimum Acceptable Results	CHEMICAL	Minimum Acceptable Results
Hydrochloric Acid 10%	2	Ethylene Dichloride	1
Benzene	1	Acetic Acid 5%	1
Hydrochloric Acid 37%	2	Heptane	1
Carbon Tetrachloride	2	Acetic Acid. Glacial	1
Nitric Acid 40%	1	Isooctane	1
Dimethyl Ether	1	Kerosene	1
Nitric Acid 70%	1	Oleic Acid	1
Dimethyl Formamide	1	Methyl Alcohol	1
Sulfuric Acid 60%	1	Phenol Solution 5%	1
Toluene	1	Sodium Hydroxide 60%	1
Alkaline Solutions — Corrosive	1	Olive Oil	1
Organic Compounds	1	Sodium Hypochlorite Sol. 4%	1
Ammonium Hydroxide 10%	1	Soap Solution 1%	1
Aniline	1	Potassium Hydroxide 15%	1
Sodium Carbonate Sol. 20%	1	Transformer Oil	1
Mineral Oil	1	Turpentine	1

1. **Hardness** (ASTM D785):
   a. **Test method:** Hardness Rockwell M Scale: average of five readings.
   b. Minimum acceptable test results: Average value of 100 over the five samples.
2. **Water absorption** (ASTM D570):
   a. **Test method:** Specimens measuring 3 inches in length by 1 inch in width by the thickness of the material should be used. At least three specimens should be tested. After weighing, specimens should be entirely immersed in distilled water maintained at a temperature of 23 degrees C plus or minus 1 degree for a period of 24 hours. The samples should then be removed, dried, and weighed to the nearest 0.001 g. The percentage of increase in weight calculated to the nearest 0.01 percent should then be calculated.
   b. **Minimum acceptable test results**: 0.01 percent.
3. Flammability or rate of burning (ASTM D635)
   a. **Test method:** Measure "Average Time of Burning (ATB)" as described in test. At least five samples (125 mm, plus or minus 5 mm in length by 12.5 mm, plus or minus 0.2 mm in width) should be tested.
   b. **Minimum acceptable test results**: ATB should equal zero.
4. **Porcelain crucible — Test A (non-standard test)**:
   c. **Test method:** A high-form porcelain crucible, size D, 15ml capacity, shall be heated over a Bunsen burner until the crucible bottom attains an incipient red heat. Immediately, the hot crucible shall be transferred to the top surface and allowed to cool to room temperature.
   d. **Minimum acceptable test results**: Upon removal of the cooled crucible, there shall be no blisters or cracks. Slight dulling or color change is acceptable.
5. **Heat deflection at 264 psi** (ASTM D648): Minimum acceptable test results shall be 193 degrees C (380 degrees F).

6. **Falling ball impact resistance** (ERF 23-69):
    a. **Test method:** Careful attention to details of test procedure should be followed. A wooden supporting frame must be used with the test. Size of samples: 12 by 12 inches by the thickness of the material. Two-lb. steel balls should be used. Three or more samples should be tested. Maximum height of 8 feet.
    b. **Minimum acceptable test result**. No fracture to a height of 7 feet.
7. **Thermal shock resistance (non-standard test)**:
    a. **Test method:** Two cubes (2 by 2 inches by thickness of material) are immersed in a dry ice / acetone bath maintained at minus 78 degrees C. The cubes can remain in the bath for 15 minutes. Each cube is removed and immediately placed in a container of boiling water at 100 degrees C. The procedure is repeated for a series of five repetitions or until failure occurs (i.e., cracking, warpage, distortion).
    b. **Minimum acceptable test results:** No visible changes should be observed.
8. **Flexural strength and flexural modulus** (ASTM D790):
    a. **Test method:** Test specimens should be prepared from 1–inch-thick production material with a support span 16 times the depth (thickness) of the beam. The original surface of the sample should be unaltered. Recommended sample size is 19.5 inches by 1 inch by 1 inch (length x width x depth). A minimum of five samples are to be tested. Testing should be carried out to failure of the test sample. Modulus of rupture should be measured as described in the ASTM method.
    b. **Minimum acceptable test result**: Flexural strength 10,000 psi, flexural modulus 1,000,000 psi.

3) Epoxy Resin Sinks:

i. Manufacturer: Durcon Incorporated or approved equal.

ii. Description: Integrally molded from filled thermosetting epoxy resin and oven cured, nominal wall thickness of 1/2 inch with all interior corners coved to 1–1/2–inch radius and bottoms pitched to the outlet opening.

iii. No drop-in sink allowed. Sinks in lab space to be under mounted.

iv. Sealant: Join work surface and sinks with a lab grade silicone as required

v. Sink color: Black onyx, stainless steel, or to match countertop.

vi. Sink outlets: Polypropylene (industry standard):

a) Sink outlets shall accommodate a plastic disc strainer. Provide outlet with 1.93–inch outlet opening and 1.5–inch NPSM threads.

b) Outlet color: Black or coordinate with Caltech PM.

vii. Sink overflows:

a) Sink overflows shall be molded polypropylene.

b) Sink overflow shall have an open intake located at least 2 inches lower than the sink rim when installed. The overflow shall taper to fit 1.93–inch outlet openings.

viii. Cup Sinks:

a) Manufacturer: Durcon Incorporated or approved equal.

b) Epoxy Resin Cup Sinks or Polypropylene:

i) Flush mounted cup sinks shall have molded polypropylene or epoxy resin cove inside corners and pitch bottom to integral 1–1/2-inch NPSM threaded outlet.

i. SERVICE FITTINGS / LABORATORY FITTINGS

1) Water Service Fittings:

i. Water service faucets and valves shall have a renewable unit containing all working parts subject to wear, including replaceable stainless-steel seat. Unit shall have serrations for position locking into valve body.

ii. **Gooseneck, no vacuum breakers**: Brass forgings integral with gooseneck, with renewable seat and special design valve member for fine flow control.

iii. Goosenecks shall have separate 3/8–inch IPS coupling securely brazed to gooseneck to provide full thread for attachment of anti-splash outlet fittings, serrated tips, and filter pumps.

2) **Air, Gas, and Vacuum Systems Fittings**:

i. **Needle valves:** Small pattern needle valve, straightway type with stainless steel replaceable floating cone and brass seat (non-renewable). Ten-serrated ends are integral with valve body.

ii. **Ball valves:** Laboratory ball valve certified for gas service by CSA International under ANSI Z21.15.1997 / CGA 9.1–M97. Internal check valve prevents backflow into piping system. Mounting shanks for air and vacuum are 3/8–inch IPS brass with 0.135–inch wall thickness. Mounting shanks for gas are 3/8–inch IPS heavy wall black iron pipe.

3) **Distilled Water Faucet and Valves:** Polypropylene or tin-lined, polished chrome finish with rigid gooseneck and removable ten-serrated hose end, arranged for manual operations. No poly-tubing end connection allowed. Final fixture connection to DI water pipe shall be made using stainless steel tubing (i.e., no plastic connection).

i. Note: these DI fixture requirements may change if job conditions dictate.

4) **Steam Fittings:** Bonnet assembly like needle valve fixture. Provide valve stem with flat Teflon valve disc and renewable, stainless steel valve seat.

5) **Turrets for Gas, Air, Vacuum, Steam, or Water Fixtures**: “Round” type design, provided with brass shanks, locknuts, and washers.

6) **Handles for Service Cocks, Faucets, and Remote Controls**: Four-arm type except ball valves that have lever handles. Provide removable screw-on type colored plastic discs with letter stamped on disc in contrasting color as scheduled below:

SERVICE	DISC / LETTER COLORS[2]	LETTERS
Gas	Blue / White	G
Vacuum	Yellow / Black	V
Compressed Air	Orange / White	A
High Pressure Air[1]	Orange / Black	HPA
Industrial Cold Water	Green / White	ICW
Industrial Hot Water	Red / White	IHW
Steam	Black / White	STM
Chilled Water Supply / Return	Brown / White	CHWS / CHWR
Deionized Water	White / Black	DI
Special Gas	Light Blue / Black	G1 (G2, G3, G4…)

[1]This is considered high-pressure air and will require a regulator. Verify prior to bid if regulator is to be supplied by casework installer or plumber.

[2]Disc color for special services as determined by design professional or Caltech.

7) **Fixture Finish:** Chrome finished with clear epoxy coat developed by the following sequence of plating over properly prepared brass castings or forgings:

PLATING	MINIMUM PLATING THICKNESS
Copper (Initial)	0.000050 inch
Nickel	0.000350 inch
Chromium (Final)	0.000015 inch

8) **Electrical Fixtures and Fittings:** Flush, pedestal, or line type; provided in strict accordance with the current edition of the National Electrical Code (NEC) of the National Fire Protection Association and with requirements of all local regulatory authorities.
   i. **Pedestal and line type housings**: Heavy "LustreBrite" corrosion-resistant aluminum alloy polished to chrome-like color.
      a) **Pedestals:** Provide with integral bases, low design for use on either single or double faces.
      b) **Line type housings:** Similar in design to pedestals; designed to be self-supporting when installed with rigid conduit.
   ii. **Receptacles:** Rated 120 volts A.C. at 20 amps, three-wire grounding type with automatic ground feature. Provide single or duplex receptacles as required. Color of molded thermo-set bodies to be coordinated with Caltech PM.
   iii. **Under-shelf Task Light Switches:** Single pole, toggle type, and occupancy sensor with dedicated task light receptacle.
   iv. **Flush boxes:** Galvanized steel.
   v. **Flush plates:** Chrome plated or nylon plastic.
   vi. **Conduit:** Rigid type, of size to accommodate easy pulling of wire. Boxes, component parts, and fittings shall be the screw type. Provide enamel finish on exposed conduit and ferrous fittings.
   vii. Pedestal and line housings, flush boxes, receptacles, and flush plates must be grounded.
   viii. Locations of all electrical fixtures and wire mold to be coordinated to avoid conflicts with other lab fixtures, such as gas valves, etc.
   ix. **Listing and Labeling:** Electrical components, devices, and assemblies incorporated into laboratory casework or service fittings shall be listed and labeled for the intended application by a recognized testing agency.

j. LABORATORY ACCESSORIES

1) **Pegboards:** Epoxy or stainless steel as specified by designer or Caltech.
   i. **Board**: Epoxy resin board finished on face and edges. Where exposed, finish back with slightly different surface texture and bevel bottom edges. All epoxy pegboards to come with 4–inch-deep stainless steel drip trough with center outlet with stainless steel screen inserts, with poly drain tube, and hose clamp to attach hose to trough drain spigot. Ensure proper location of drain spigot with Caltech PM. If for reason of design 2–inch drain troughs are required due to interference with fixtures or placement of umbilical etc., casework installer will exchange at no charge to Caltech provided adequate info was provided in advance to Caltech to review. If edges of pegboard extend beyond edge of umbilical, then casework installer will be required to furnish pegboards with finished backs to match front finish.
   ii. **Pegs:** Black or white polypropylene pegs in 5–inch, 6–1/2 inch, and 8–inch lengths, with glassware protector base. Base of pegs shall be two-prong type for mechanical attachment. Do not bond pegs to board.
   iii. Color to match countertops.
   iv. Where back of epoxy resin pegboard is exposed, fill in exposed areas of epoxy resin with filler to provide a smooth and even surface.

v. **Task lights:** Bartco, Mocha, or approved equal. Low-profile, under-shelf mount style, with length as long as practical with LED bulbs, occupancy sensor with on/off, and rocker switch with cord and jumper and driver as required. Brackets and all required fittings to mount on shelf or under cabinet.
   a) Other brands of task lights if required, will be identified at time of bid as to brand and whether, if specified, to be provided by this section of work.
   b) Hardwired task light is not acceptable. A dedicated task light receptacle is needed on wall, with label "Task Light Use Only."
   c) Task lights to have color temperature to match the color temperature of the room.
   d) Task lights to have built-in occupancy sensor. Consult with Caltech PM for task light within blackout area or area sensitive to light.
   e) Task lights to have dedicated power outlets, horizontally oriented and located as close as possible to underside of upper cabinets. Consult with Caltech PM on maximum number of allowable daisy chain task lights on each room elevation as electrical circuits and manufacture allow for.

3. EXECUTION

a. INSTALLATION

1) **Furniture Installation**:
   i. Set furniture components plumb, square, and straight with no distortion, and securely anchored to building structure. Shim as required using concealed shims.
   ii. Fasten continuous cabinets together with joints flush, tight, and uniform, with alignment of adjacent units within 1/16–inch tolerance.
   iii. Secure wall cabinets to metal backing or existing studs, not to plaster, lath, or gypsum board. No toggle anchor is allowed. Install steel backing in wall.
   iv. Abut top edge surfaces in one true plane. Provide flush joints not to exceed 1/8–inch between top units.
   v. Provide certificate from WI certifying that the casework, including installation, will be completed by a WI-certified installer.
2) **Work Surface Installation**:
   i. Where required due to field conditions, scribe or caulk to abutting surfaces.
   ii. Secure joints in the field, where practical, in the same manner as in factory with dowels, adhesive, or fasteners recommended by manufacturer.
   iii. Secure work surfaces to furniture and equipment components with material and procedures as recommended by the manufacturer.
3) **Sink Installation:** Sinks shall be set in chemical-resistant sealing compound, secured, and supported per manufacturer's recommendations.
4) **Accessory Installation:** Install accessories and fittings in accordance with manufacturer's recommendations. Turn screws to seat flat. Do not drive.
5) **Fixture installation**: For basis of bid, casework installer will assume to install all fixtures "hand tight" in holes at least a week prior to plumber starting final connection. This is to minimize the chance that fixtures are lost or are incorrect, or quantities are incorrect.
6) If by prior arrangement with the GC plumber and Caltech PM, a different method of material turnover can be accomplished with all parties' consent, then setting of fixtures in place by hand may be remanded. For basis of bid assume that all fixtures are to be installed in fixture holes "hand tight."
7) **Cylinder Racks:** To be built of powder strut tube steel complete with all struts to include top and lower horizontal rails with intermediate upright vertical posts all bolted together in field includes all cover plates, two top eyebolts, 18 inches long, ¼–inch by 2–inch link steel chrome plated chains, with double end safety chain snaps, double support angles, painted: powder coat. Provide rigid polycarbonate mat under cylinders.

b. ADJUSTING / SCHEDULING

1) Repair or remove and replace defective work, as directed by Caltech PM upon completion of installation.

2) Adjust doors, drawers, hardware, fixtures, and other moving or operating parts to function smoothly.

3) Contractor to keep a log of running punch list items once casework installation is 50 percent complete, or at the halfway point in Caltech's / contractor's viewpoint of where we should be with regards and in accordance to finish schedule date. Then, contractor will submit punch list to casework installer on a weekly basis after each job meeting. This will allow casework installer to have notice and allow Caltech to be kept up to date on all outstanding issues, so that all parties can be aware of conflicts, shortages, design, and/or other trade schedule changes, and any other job site conditions that may impact casework installer's ability to order and expedite any long lead items. This will serve to keep a written record of when a problem or conflict was first noticed, when casework installer was notified of conflict, and when a date can be established as to what actions must be taken to rectify conflict or shortages.

c. CLEANING AND PROTECTION

1) Repair or remove and replace defective work as directed by Caltech PM on completion of installation.

2) Clean finished surfaces, touch up as required. Clean pull boards, vacuum out drawers and cabinets, remove all tape and markings from shippers, etc.

3) Clean top materials as recommended by manufacturer.

4) Provide heavy gauge corrugated cardboard on top of countertop for the duration of the construction period. Provide "DO NOT STAND" signs for all countertops.

5) Employ procedures and precautions for protection of material, installed laboratory furniture, and fixtures from damage by work of other trades. Without approval from Caltech PM, if any damage occurs as a result of field installation or transportation from factory, contractor shall be responsible for damage. Contractor or/and vendor shall be responsible for schedule delay resulting from any damage.

Section 12 35 53.13 – Metal Laboratory Casework

1. General: Refer to Section 12 35 53 Laboratory Casework, Parts 1 and 3. All provisions of those sections apply to metal laboratory casework unless more stringent requirements are specified herein. Metal laboratory casework shall comply with SEFA 8M in addition to SEFA 8 requirements.

a. Overview:

1) Metal laboratory casework including painted steel and stainless steel cabinets, countertops, tables, shelves, utility-space framing, filler and closure panels, sinks, accessories, and service fittings.

b. Performance Requirements:

1) Metal Materials and Thickness

i. Cold-Rolled Steel:

a) Comply with ASTM A1008

b) Minimum thickness:

i) Cabinet body panels: 0.048 inch

ii) Structural members: 0.060 inch

iii) Reinforcements and supports: 0.075–0.105 inch

ii. Stainless Steel:

a) Comply with ASTM A240

b) Type 304 unless otherwise noted

c) #4 finish at exposed surfaces

2) Metal Fabrication: Fabricate metal casework components using methods that produce units that are rigid, square, dimensionally stable, and free from distortion. Fabricate and finish components to provide smooth, durable surfaces suitable for laboratory environments.

i. Construction:

a) Casework shall be of welded or mechanically fastened construction.

b) Finish exposed surfaces smooth and free of sharp edges, projections, and visible defects.

c) Units shall be rigid, square, and free from distortion.

ii. **Cabinet Design**:

a) Provide double-wall construction where required for durability and performance.

b) Provide removable backs or access panels for service access.

c) Reinforce load-bearing components as required to meet specified performance requirements.

iii. **Exposed Edges**: All exposed edges shall be smooth and free of sharp edges.

3) **Metal Finish System**

i. **Painted Steel**:

a) Apply electrostatically applied powder coating.

b) Finish shall be oven cured.

c) Minimum thickness: 2–3 mil.

ii. **Pretreatment**: Provide phosphate or zirconium pretreatment for corrosion resistance.

iii. **Performance**:

a) Finish shall comply with SEFA 8 chemical resistance testing.

b) Finish system shall demonstrate resistance to impact, abrasion, and corrosion in laboratory environments.

c) No blistering, peeling, or visible corrosion permitted.

iv. **Verification**: Provide documentation or test reports demonstrating compliance with SEFA 8 finish performance requirements.

4) **Structural Performance**: Metal casework systems, including cabinets, frames, and supports, shall support specified loads without permanent deformation, binding of components, or excessive deflection. Comply with structural performance and deflection requirements of Section 12 35 53.

5) **Quality Assurance**

i. **Mockups:** Mockups shall include metal casework systems, support framing, service carriers, and utility integration components where applicable.

ii. Standards and certifications

a) Flammable Liquid Storage: Where cabinets are indicated for solvent or flammable liquid storage, provide painted steel units that are UL listed and labeled as complying with requirements in NFPA 30 by a testing and inspecting agency acceptable to authorities having jurisdiction.

b) Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

6) **Sustainability**

7) **Submittals**

i. See Appendix II, submittal register

8) **Warranties**

i. See Appendix II, submittal register. Warranty for metal casework shall comply with requirements of Section 12 35 53.

c. **Product Requirements:**

1) Provide seismic analysis data for laboratory casework where required by code, signed and sealed by the qualified professional engineer responsible for their preparation. Laboratory casework, including attachments to other work, shall withstand the effects of earthquake motions determined according to CBC.

2) Pull-out work surface shelf (breadboard) made of stainless steel. Design shelf, shelf slides, and hardware to support 100–pound load.

3) Provide under-counter task lighting at wet benches and desk areas.

4) Provide stainless steel hinges, door, and drawer pulls.

5) **Drawer suspension**: Side-mounted, full extension, zinc coated.

i. Accuride 3832 regular or easy close
   a) Up to 100 lbs
   b) Up to 36 inches wide
ii. Accuride 4034 regular or easy close
   a) Up to 150 lbs
   b) Up to 42 inches wide

6) **Acid Storage Cabinets:** Acid storage cabinets shall be constructed of painted steel, stainless steel, or non-metallic materials suitable for corrosive environments and shall be lined with chemically resistant molded polyethylene. Lining shall be 3/16–inch-thick molded polyethylene lining with coved corners and 1 inch lip at front of cabinet opening. Cabinets to include removable back panel with two vent cutouts in the cabinet back. Doors to be lined with 1/8–inch-thick polyethylene. Shelving is half depth with polyethylene spill tray. Cabinets shall be suitable for storage of corrosive chemicals and designed to resist chemical attack, leakage, and vapor accumulation.
7) **Stainless Steel Work Surfaces and Sinks:**
   i. Provide Type 304 stainless steel work surfaces with No. 4 finish unless otherwise noted. Fabricate and install work surfaces to provide smooth, durable, and cleanable surfaces suitable for laboratory use.
   ii. Form tops with required edges, returns, and reinforcing to provide rigidity, sound dampening, and long-term performance.
   iii. **Sink Tops**: Fabricate sink tops to provide a seamless appearance at sink locations. Provide sound-dampening material at the underside of sink bowls.
   iv. Integrate sink bowls with countertops to provide a smooth, durable, and cleanable assembly. Finish exposed joints to provide a uniform appearance free of visible irregularities.
   v. **Joints**: Fabricate joints to provide smooth, durable, and sanitary surfaces. Finish exposed joints free of sharp edges, projections, gaps, or irregularities that would interfere with cleaning, appearance, or performance. Where field-made joints are required, provide reinforcing and alignment devices as necessary to maintain rigidity, alignment, and a smooth finished appearance.
   vi. **Welded Assemblies**: Where welding is used, grind and polish exposed welds to produce a uniform, directionally textured finish free of cross scratches. Upon completion of polishing, passivate and rinse surfaces. Remove embedded foreign matter and leave surfaces chemically clean.
   vii. **Field Joints**: Keep field joining to a minimum where practical. Where field-made joints are required, fabricate and finish joints to match adjacent surfaces and maintain continuity of appearance and performance.
8) **Metal Cabinets and Tables:** Provide metal casework constructed of painted steel or stainless steel as appropriate for the application.
   i. **Structural Performance Requirements**: Comply with structural performance requirements of Section 12 35 53.
   ii. **Table Frames**: Provide framing members sized and reinforced as required to meet specified performance requirements.
   iii. **Legs**: Attach legs and structural components using methods necessary to achieve the specified structural performance and rigidity. Provide adjustable leveling devices.
   iv. **Chemical-Resistant Finish**: Provide factory-applied finish systems suitable for laboratory environments and resistant to chemicals, cleaning agents, and normal wear. Stainless steel surfaces shall have a No. 4 brushed finish unless otherwise noted.
   v. **Chemical and Physical Resistance of Finish System**: Finish systems should comply with SEFA performance requirements for laboratory casework and demonstrate resistance to chemicals, cleaning agents, staining, and normal laboratory use.

9) **Hardware:** Hardware for metal casework shall comply with Section 12 35 53 and shall be corrosion-resistant and suitable for laboratory environments.
10) **Racks:** Provide cylinder racks sized and configured as required by the application. Coordinate rack configuration, mounting requirements, and protective features with the Caltech PM and Carpenter Shop.
    i. Provide 1/4–inch clear polycarbonate sheets with chamfered edge at all exposed sides underneath cylinder tanks.

d. Installation Requirements:

1) Comply with installation requirements in SEFA 2.3. Install level, plumb, and true; shim as required, using concealed shims. Where laboratory casework abuts other finished work, apply filler strips and scribe for accurate fit, with fasteners concealed where practical. Do not exceed the following tolerances:
    i. **Variation of Tops of Base Cabinets from Level**: 1/16 inch in 10 feet.
    ii. **Variation of Bottoms of Upper Cabinets from Level**: 1/8 inch in 10 feet.
    iii. **Variation of Faces of Cabinets from a True Plane**: 1/8 inch in 10 feet.
    iv. **Variation of Adjacent Surfaces from a True Plane (Lippage)**: 1/32 inch.
    v. **Variation in Alignment of Adjacent Door and Drawer Edges**: 1/16 inch.
2) **Countertops**: Comply with installation requirements in SEFA 2.3. Abut top and edge surfaces in one true plane with flush hairline joints and with internal supports placed to prevent deflection. Locate joints only where shown on Shop Drawings.

e. Field Control, Evaluation, Commissioning:

1) Inspect installation and verify work is complete and properly installed.

Section 12 91 00 – Interior Waste and Recycling Receptacles

General: Substitutions and placement locations of the following items require approval from Caltech Planning, Design & Construction and FOS Building and Grounds.

1. Laboratory and Common Area Recycling Containers:

Provide 23–gallon blue recycling containers by Rubbermaid Commercial Products (Slim Jim series) or Continental Commercial Products. Units shall be suitable for commercial institutional use.

2. Recycling Lids:

Provide compatible 23–gallon recycling lids for containers, color-coded for waste stream identification in accordance with campus standards.

3. Office Recycling Wastebaskets:

Provide 7–gallon blue recycling wastebaskets by Rubbermaid Commercial Products for office areas. Units shall be suitable for commercial institutional use.

DIVISION 13 – SPECIAL CONSTRUCTION

Equipment Sustainability Principles:

Energy modeling should be performed to support life-cycle cost evaluation. All large equipment should maximize energy efficiency and performance to the greatest extent possible given project scope, budget, and schedule constraints. Placards containing building user guides promoting the AiM Facilities Service Request system, energy/water conservation, and proper waste practices shall be provided by the project contractor in coordination with the Caltech project manager and sustainability manager.

Section 13 21 00 – Controlled Environment Rooms (Cold/Warm Room)

1. General

a. Provide a controlled environment room with interior temperature as required to meet the building specific program. Minimum temperature tolerance is ± 2°C unless otherwise noted.
   1) 4–inch thick insulated walls and ceiling
   2) 22-ga stainless steel, interior and exposed walls
   3) 26-ga embossed galvanized steel, unexposed walls
   4) 2–inch insulated floor installed on grade with interior ramp
   5) 16-gauge stainless steel, flooring

b. Provide 36–inch x 81–inch insulated self-closing swing doors.
   1) Door shall be thermally insulated and include observation window, inside safety release latch, cam-type self-closing hinges, thermal plastic gasket with magnetic core, and doorstop.

c. Provide and Install vapor-proof LED light fixtures.

d. Provide suspended ceiling grid with “egg-crate” ceiling tiles. Tiles to be easily removable.

e. Provide low-height evaporator fan coil with copper tube / aluminum fin design and aluminum housing.
   1) Condensate drain line piped to discharge indirectly into the sink tailpiece or other approved receptor per current edition of the California Plumbing Code.

f. Provide programmable logic controller-based controls with 6” color touchscreen.
   1) Controller to be capable of temperature control and alarm notification and correction handling.
   2) Provide personnel emergency alarm function

g. Provide (2) sets of dry contacts within the console for remote alarm notification.

h. Provide 10” circular chart recorder.

i. Provide all final electrical connections from the controls console to the chamber components.

j. Provide remote, semi-hermetic condensing unit located above chamber roof.
   1) Provide refrigeration piping between condensing unit and evaporator coil.
   2) Provide ancillary components for hot-gas bypass temperature control.
   3) Electrical requirements to chamber controls: 120Volt – 20Amps
   4) Complete final power service connections to room components, power wiring, and disconnect.

k. Testing
   1) Evacuate system to below 500 microns for a minimum of 2-hours.
   2) Document vacuum extremes and provide at turnover.
   3) Acceptance testing shall consist of sustained operation at design temperature condition for a minimum period of 24 hours.
   4) 12-point temperature mapping for 24 hours with total deviation of ≤ 0.5°C from set point.
   5) Furnish recorder test chart to the GC.
   6) Provide demonstration and training of proper room operation and maintenance.

7) Provide turnover documentation to include the following:
- **(a)** Vacuum Test (certified by technician)
- **(b)** Temperature charts (certified by technician and witnessed by Caltech)
- **(c)** Field configured controller values

l. Insulated Room
- **1)** Insulation: Polyurethane foam/ (2.2 lbs. /sq. ft)
- **2)** Wall and Ceiling: 4" thick insulated
- **3)** Floor: 2" thick insulated

m. Swing Door
- **1)** Net Opening: 36" x 81"
- **2)** Style: Insulated panel with observation window
- **3)** Finish: Similar to walls
- **4)** Handle: Lockable
- **5)** Hardware: Polished Chrome Finish

n. Mechanical
- **1)** Condensing Unit: Primary water-cooled / indoor / semi-hermetic with air-cooled backup. Refer to detail "DTL 24" in Appendix XX for hydronic piping.
- **2)** Air-cooled condensing unit is only allowed when water-cooled is not practical or cost effective. Caltech project manager shall provide directive in writing.
- **3)** Location: Above cold room
- **4)** T-grid ceiling: An option, but not preferred
- **5)** Evaporator Fan Coil: Aluminum housing / copper tube / aluminum fin

o. Lighting
- **1)** Design: Minimum 70 foot-candles at 40" A.F.F.
- **2)** Type: LED
- **3)** Style: Vapor-proof, surface mounted
- **4)** Finish: PVC housing and polycarbonate diffuser
- **5)** Light Switch: Inside control room and exterior at control panel.

p. Mold Insurance
- **1)** As a preventative measure against mold, each room must have an absolute minimum of 2" between the insulated walls. Clearances between the building and insulated walls are established at the time of field dimensions.

q. Refrigeration Control: Refrigeration systems are 3-pipe style. Hot gas (discharge routed around the condenser) is proportionally controlled ahead of the evaporator expansion device providing non-cycling compressor operation. This function provides tighter control of temperature range. Condenser shall be water-cooled unless otherwise noted. Air-cooled condensers require prior approval from Caltech project manager.

r. The evaporators are low-silhouette style installed at the ceiling within the chambers. The evaporator fans operate continuously. A minimum of 15˚F delta T should be provided across the coil, to minimize mold growth.

s. Control Console: All control equipment including power distribution, fuses, recorder, alarm annunciation, and service disconnect are located in the control console installed on the front wall of the CER. (See Section **9. Control Console Standard Features** for additional requirements.)

t. Recording: Room temperatures and humidity are recorded via a 10" circular electronic function chart recorder located in the control console. The recorder maintains 24-hour, 7-day trending of conditions within the cold room. (See Section **11. Chart Recorder** for additional requirements.)

u. Remote Alarms: The console is equipped with alarm dry contacts for remote annunciation of chamber temperature excursion; personnel emergency; controller failure and loss of power. (See Section **1.x Alarms** for additional requirements)

v. Temperature Sensors: 100 ohm, 3-wire RTDs (resistive temperature device) are provided for both control and recording temperature within the chambers. Each chamber is fitted with two (2) temperature control sensors. The control sensors are averaged at the controller for an accurate chamber temperature. The dual control sensor setup provides redundancy in the event of a single sensor failure. Sensor #3 connects to the chart recorder installed in a glycerin bath to buffer door operation temperature spikes. (See Section **10. Temperature Sensor** for additional requirements)

w. Lighting: Fluorescent vapor-proof light fixtures are installed in the cold chambers. The fixtures are connected electrically at the control console and may be energized manually with the screen switch or automatically via diurnal programmability. Light output is approximately 70 foot-candles. (See Section **1.o Lighting** for additional requirements.)

x. Alarm Functionality:

1) Temperature alarm functionality is linked with temperature setpoint as the alarm temperature is set up as a deviation (of setpoint). Alarm deviation set points are user configurable from 0.1°F to 10.0°F. In addition to the individually configurable deviations, each temperature alarm can be delayed (in minutes) to eliminate nuisance alarm annunciation.

2) Low Temperature Alarm Function (cold rooms only)

(a) LOW TEMPERATURE is indicated at interface status line when temperature exceeds deviation.

(b) Following the configured delay period:

i. Audible horn energized in 1–sec pulse
ii. Remote alarm (Corresponding Dry Contacts) relay is de-energized (Off)
iii. Evaporator fans are de-energized (Off) to avoid freezing condition within CER
iv. Audible alarm is manually silenced with MUTE button at the interface

(c) Condition will automatically reset with correction of Low Temp Condition

3) High Temperature Alarm Function

(a) HI TEMPERATURE indicated at interface status line when temperature exceeds deviation.

(b) Following the configured delay period:

i. Audible alarm is energized (On)
ii. Remote alarm (corresponding dry contacts) relay is de-energized (Off)
iii. Audible alarm is manually silenced with MUTE button at the interface

(c) Condition automatically reset with correction of High Temp Condition

4) Audible Alarm Mute

(a) Piezo-horn on the console is silenced for 60 minutes with MUTE button at the interface

(b) Audible condition continues until alarm condition corrected

(c) No reset required to re-establish operation

(d) Remote relay (dry contacts) not effected by alarm mute

5) Remote Alarm (dry contact) Operation:

(a) Remote alarm relay(s) are energized during normal operation

(b) Alarm conditions corresponding to the relay de-energize the relay

(c) Remote alarm not affected by MUTE button

(d) Automatically resets on termination of alarm condition

6) Personnel Emergency Alarm

(a) The chamber is equipped with a red mushroom-head, sustained push-button style switch installed in a flush mounted j-box at 12” above the floor adjacent to the handle side of the entrance door (PEA actuator). In the event a user in the chamber is incapable of exiting, the button is pressed with the following results:

i. All components (fan, solenoids heaters) are de-energized (Off)
ii. The chamber lights are energized (On) if not already

iii. The interface screen changes to indicate the emergency and to "Check Inside the Room"
iv. The piezo horn is energized continuous, different from temp or failure alarms
v. Remote alarm (corresponding dry contacts) relay is de-energized (Off)
vi. The horn is not mutable and only reset by pulling the PEA actuator

(b) On reset the horn is de-energized and the chamber is restored to normal operation

2. Defrost Sequence

a. Maximum (4) programmable defrost events
b. Setup event start time 00 (midnight) – 23 (11:00 pm)
c. Set Duration 0 – 30 minutes
d. Defrost Sequence of Operation:
i. Liquid and hot-gas solenoids are de-energized (Off) / Evaporator fans remain On
ii. System returned to normal operation following defrost duration
iii. Fans delayed via onboard evaporator fan delay

3. Insulated Panels

a. Prefabricated modular insulated panel designed for field assembly and future expansion
b. 4–inch foamed-in-place closed-cell polyurethane insulation
c. Panel system shall utilize concealed mechanical locking devices and gasketed joints to provide an airtight and vapor-tight enclosure and prevent condensation and air infiltration
d.

4. Chamber Heat Load Calculations

a. Cold Room; temperature required: 4°C
b. The following criteria are used for heat load calculation:
i. 6-Watts per square foot heat-load
ii. System run time of 22 hours cooler
iii. One (1) person for 24 hours cooler
iv. Fans and lights on 24 hours
v. Ambient temperature 95°F
vi. 10% safety factor

5. Air-cooled Condensing Unit

a. Installation of air-cooled condensing units requires prior approval from the Caltech project manager.
b. Code approved refrigerant; medium temp application
c. Air-cooled
d. Copeland semi-hermetic compressor
e. Located above chamber

6. Indoor Water-Cooled Semi-Hermetic Condensing Unit

a. Application: Code approved refrigerant; medium temp application
b. Standard Features:
1) Coaxial water-cooled condenser
2) Electrical control panel with compressor contactor and fused control circuit
3) Resilient mounted, semi-hermetic compressor
4) Piping secured with hydra-zorb clamps
5) Receiver with fusible plug and liquid and hot gas shutoff valves
6) High/low pressure controls
7) Hose style pressure control fittings
c. Additional Features:
1) UL listed control enclosure
2) Sealed liquid line filter drier and sight glass

7. Evaporator Fan Coil

- **a.** Low profile – Two Way
- **b.** Copper tube — aluminum fin coil
- **c.** Heavy gauge aluminum housing
- **d.** Air defrost style coil

8. Low Profile Evaporator Unit

- **a.** Compact flush to ceiling design featuring internally enhanced tube technology.
- **b.** Optimized storage space by a compact, slim profile, which provides uniform air distribution through the coil for maximum heat transfer performance.
- **c.** Textured aluminum cabinet
- **d.** Hinged drain pan with central universal drain connection
- **e.** Front access to spacious electrical and header compartments
- **f.** Factory installed solenoid valve wire harness
- **g.** Schrader connection on suction header
- **h.** Electric defrost units are equipped with electric resistant core and drain pan heaters
- **i.** Fan delay switch and overheat protection
- **j.** The coil includes energy efficient EC (electronically commuted) motors, factory installed
- **k.** Expansion valve and hot-gas bypass side port access fitting.

9. Control Console Standard Features:

- **a.** Front service disconnect
- **b.** Console lock
- **c.** Touch screen operator interface
- **d.** Audible temperature alarm
- **e.** Honeywell circular chart recorder
- **f.** Temperature monitoring and trending
- **g.** Configurable temp-alarm delays
- **h.** Real time function programmable
- **i.** Light timing component maintenance and testing compressor
- **j.** Operational status audio alarm mute
- **k.** Non-volatile memory
- **l.** Alarm logging
- **m.** On-screen sensor calibration
- **n.** Personnel emergency annunciation password protection to maintenance
- **o.** User-friendly language and navigation
- **p.** Service disconnect
- **q.** Dual locking hasps for security for interior components of console
- **r.** Touch screen operator interface menu driven screens interface
- **s.** User with system operation and control configuration. All alarms and alarm indications are clearly indicated on screen.
- **t.** Auto-return from maintenance screens to monitor screen
- **u.** Audible temperature alarm 95 dB piezo-electric horn
- **v.** Circular chart temperature recorder, see section **11. Chart Recorder** below for additional requirements.

10. Temperature Sensor

- **a.** Probe type temperature sensor, similar to Greystone Model #TE200
- **b.** 100 Ω Platinum RTD
- **c.** Stainless Steel Encapsulated

11. Chart Recorder

a. Analog type chart recorder, similar to Honeywell Model #DR4301
b. Single pen recorder
c. 10” circular chart
d. –30°C – +70°C / 7–day chart

Section 13 21 13 – Clean Rooms

1. Portable (Modular) Clean Rooms: Coordinate requirements with Caltech project manager.

a. Portable cleanroom enclosures must be equipped with sprinkler heads as required for full coverage at the ceiling of the enclosure.

DIVISION 14 – CONVEYING EQUIPMENT

Section 14 20 00 – Elevators

1. **Overview:**
   - **a.** Traction and hydraulic passenger elevators
   - **b.** Service elevators
   - **c.** Freight elevators
2. **Performance Requirements:**
   - **a.** Quality Assurance
     - **1)** Mock-ups
     - **2)** Standards and certifications
       - **a)** Comply with current edition of ASME A17.1, or edition acceptable to local authorities having jurisdiction, and U.S. Architectural & Transportation Barriers Compliance Board's ADA-ABA Accessibility Guidelines.
       - **b)** Comply with California Code of Regulations, Title 8 "Industrial Relations," Division 1 "Department of Industrial Relations," Chapter 4 "Division of Industrial Safety," Subchapter 6 "Elevator Safety Orders," Group 4 "Conveyance Installations for Which the Installation Contract Was Signed on or After May 1, 2008, Article 41 "Conveyances Covered by ASME A17.1-2004."
       - **c)** Comply with all applicable California Code of Regulations including Title 24.
   - **b.** Sustainability
   - **c.** Submittals
     - **1)** Submit operating and maintenance instructions, catalog of parts and recommended parts inventory, purchasing source listing for major critical components, three complete sets of final wiring diagrams, troubleshooting guides, and emergency information for the installed conveying system(s). Bind information in building operation and maintenance manual.
     - **2)** Acceptance test results.
     - **3)** Service training plan.
     - **4)** See Submittal Register, Appendix II.
   - **d.** Warranties
     - **1)** Warranty period to be one year to coincide with contractor's warranty.
     - **2)** See Submittal Register, Appendix II.
3. **Product Requirements:**
   - **a. Controller Manufacturer**: Motion Control Engineering Inc. (MCE), www.mceinc.com, or SmartRise, smartrise.us.
   - **b.** All cars to have ELSCO roller guides.
   - **c.** All hydraulic elevators to have Maxton valve on pump and scavenger pump in pit for cylinder return line to tank.
   - **d.** Mount rotating and vibrating equipment on vibration-isolating mounts to minimize vibration transmission to structure and structure-borne noise due to elevator system.
   - **e.** At least one elevator in each building shall comply with CBC 3002.4A for accommodating ambulance stretchers. Exception: Elevators in buildings or structures less than four stories in height for which the local jurisdictional authority has granted an exception in the form of a written document.

14 20 01 — Passenger Elevators:

1) **Quantity:** As determined by elevator consultant analysis, but not less than one for multi-story structures.
2) **Average Interval:** 50 seconds or less.
3) **Handling Capacity:** 8 to 10% of zone population in five minutes.
4) **Population Density**: 1.5 – 2 sq.ft. per person.
5) **Occupancy:** 100%.

Elevator Capacity Table		
Capacity (lbs.) or number of people per trip in each direction		
2500 lbs.	or	12 people
3000 lbs.	or	15 people
3500 lbs.	or	17 people
4000 lbs.	or	20 people
4500 lbs.	or	23 people

6) **Peak Traffic Condition:** Afternoon, two-way.
7) **Maximum Car Loading:** Not to exceed the rated capacity of the elevator.
8) **Minimum Size:** 4000 lbs. capacity.

   a)Inside Clear: 80 inches wide by 54 inches deep by 96 inches high.
   b)Doors: 42 inches wide by 84 inches high.

9) **Speed:** To be determined by an elevator traffic analysis with maximum of 60 upstarts per hour, but not less than 150 feet per minute for elevators with five stops or less, and 350 feet per minute for elevators with up to ten stops.
10) **Control Systems:** Caltech standard control system is Motion Control Engineering.

    a)Traction: iControl with AC flux vector drive.
    b)Hydraulic: HMC–2000 with SCR soft starter.
    c)Provide group operation for three or more cars.

11) **Door Operator:** Caltech standard door operator system is GAL Manufacturing.

    a)MOVFR closed-loop control for passenger doors.

12) **Rails:** Minimum 15 lbs. per foot "T" rails; formed rails are not acceptable. Provide spring damped roller guides.
13) **Platform:** Class "A" platform construction.
14) **Hydraulic Cylinders:**

    a)Capped steel outer casing.
    b)PVC or fiberglass soil isolation.
    c)Watertight well casing at pit floor with inspection ports.
    d)Telescopic pistons are not acceptable.
    e)Inverted cylinders are not acceptable.

15) **Signals and Fixtures:**

    a)Two car-operating panels in each elevator with center opening doors.
    b)One car-operating panel in each elevator with side opening doors.
    c)All fixtures to be illuminated with LEDs.
    d)Typical Buttons: Minimum 1–inch diameter, vandal resistant.
    e)Digital position indicator in each car: Locking cam type operating panel in elevators with more than two stops.
    f)Key or card reader security provisions in each car panel. Locate below buttons.

g) Locked service cabinet with switches for car lighting, inspection, independent service, car fan, emergency light test button, duplex outlet, and other switches to meet project requirements. Communication system, hands-free, voice-free complying with ADA requirements. Locate below key/card reader in main operating panel. The permit window needs to be on operating panel.

h) No separately applied plaques or signs permitted on car panels or lobby walls. Engrave text directly on car panel and hall button faceplates.

i) Provide vandal-resistant hall lanterns at all floors with adjustable electronic chimes and LED illumination. Dual in-car lanterns are acceptable on simplex elevators.

j) Provide digital hall position indicator at all floors; may be incorporated into hall lantern or corridor pushbutton faceplate.

16) **Car Interiors:**

a) Steel shell with plastic laminate removable wall panels or wrapped in vandal-resistant architectural metal.

b) Recommend application of a clear graffiti-resistant protective coating (Graffiti Shield or approved equal) on exposed interior wall panels.

c) Front return panels, transom, and car doors shall be #4 brushed stainless steel.

d) Use only LED car lighting and LED emergency light.

e) Interior finishes meeting ASME A17.1 for flame spread and smoke density requirements.

f) One set of moving pads is required for each elevator. Provide a set of elevator StudStrip(TM) or similar for each elevator. Coordinate installation with architectural firm.

14 20 02 — Laboratory and Service Elevators: Comply with requirements for passenger elevators, except as follows:

1) **Minimum Size:** 4500 lbs. capacity.
   a. **Inside Clear**: 68 inches wide by 94 inches deep by 120 inches high.
   b. **Doors**: 48 inches wide by 96 inches high
2) **Signals and Fixtures**: One car-operating panel in each elevator.
3) **Car Interiors:**
   a. Aluminum checker plate walls from floor to canopy.
   b. Recessed LED fixtures in stainless steel canopy without suspended ceiling.
   c. Vinyl tile flooring, or heavy-duty flooring as approved by Caltech PM.
   d. ½–inch by 2–inch stainless steel bar type handrails.
   e. 1½–inch diameter tube handrail on rear wall at 32 inches above the floor.
   f. Stainless steel fronts and doors.
   g. One set of moving pads is required for each elevator. Provide a set of elevator StudStrip(TM) or similar for each elevator. Coordinate installation with architectural firm.

14 20 03 — Parking Structure Elevators: Comply with requirements for passenger elevators, except as follows:

1) **Quantity:** As determined by elevator consultant analysis, but not less than one for multi-story structures.
2) **Average Interval:** 60 seconds or less.
3) **Handling Capacity:** 8 to 10% of zone population in five minutes.
4) **Population Density:** 1.5 people per automobile.
5) **Occupancy:** 100%.
6) **Peak Traffic Condition:** Afternoon, two-way.
7) **Maximum Car Loading:** See Passenger Elevator Capacity Table.

14 20 04 — Freight Elevators:

1) **Quantity:** Quantity and location to be as directed by architect for loading dock, building users, and Facilities purposes.

2) **Size:** To suit largest and heaviest piece of equipment to be moved with proper class of loading per code.
    a. **General Purpose Loading Dock:** 10,000-pound capacity with inside dimensions of 10 ft wide by 14 ft deep by 10 ft. high and 10 ft. by 10 ft. vertical bi-parting freight doors.
3) **Speed:** 150 feet per minute hydraulic.
4) **Platform:** Design for Class "C–3" loading.
5) **Control System:** The Caltech standard control system is Motion Control Engineering.
    a. Hydraulic HMC-2000 with SCR soft starter.
6) **Door Operator:** The Caltech standard door operator system is GAL Mfg., EMS, Peele, or Courion for freight doors.
7) **Signals and Fixtures:**
    a. One car-operating panel in each elevator.
8) **Typical Buttons:** Minimum 1–inch diameter vandal-resistant type.
    a. Digital position indicator in each car-operating panel.
    b. Digital hall position indicator at each landing may be incorporated into corridor pushbutton faceplate.
    c. Locked service cabinet for switches for car lighting, inspection, independent service, car fan, emergency light test button, duplex outlet, and other switches to meet project requirements.
    d. Communication system, hands-free/voice-free meeting ADA requirements.
9) **Car Interiors:**
    a. Aluminum checker plate walls from floor to canopy.
    b. Recessed LED fixtures in stainless steel canopy without suspended ceiling.
    c. Aluminum checker plate flooring.
    d. ½–inch by 2–inch stainless steel bar type handrails.
    e. Bumper rails at 8 inches and 24 inches above floor.
    f. One set of moving pads required for each elevator. Provide a set of elevator StudStrip(TM) or similar for each elevator. Coordinate install with architectural firm.

4. Installation Requirements

a. Elevator rooms shall be sprinklered and equipped with shunt trip devices.
b. Elevator control room shall not be near classrooms or sound sensitive areas.
c. Provide automatic fireman's recall system.
d. Provide key locks for independent service, fire service inspection, emergency stop, and fan. (Four keys for each lock.) All locks shall accommodate Caltech's standard keying system. Coordinate with Lock Shop keying schedule.

5. Field Control, Evaluation, and Commissioning

a. Payment for acceptance tests shall be the contractor's responsibility. Before permitting use of conveying system(s) — either temporary or permanent — perform acceptance tests as required and recommended by governing regulations.
b. Manufacturer's authorized service representative shall train Caltech's maintenance personnel operation, adjustment, and maintenance procedures.
c. Inspect installation and verify work is complete and properly installed.

DIVISION 21 – FIRE SUPPRESSION SYSTEMS

Section 21 00 00 – Fire Suppression System Control Valve Selection Table

Refer to the Control Valve Selection Table: 2023_Control_Valve Selection Table_V5.4

Section 21 05 00 – Common Work Results for Fire Suppression

1. General

a. All fire protection work shall be coordinated with all other applicable trades during the design and construction phases. The Contractor shall field verify routing, elevations, clearances, equipment locations, access requirements to avoid conflicts with other trades and ensure proper installation and operation of the fire protection system.

b. All spaces under renovation that are not currently sprinklered shall be retrofitted with the basic fire sprinkler infrastructure according to their hazard classification. In order to accommodate future installation of sprinkler heads, the contractor shall install fire sprinkler mains, cross mains, and branch lines capped or plugged for future connection.

c. When the renovated space has a dropped ceiling, the contractor shall provide 1" plugged openings in the branch lines within 24" of the intended future sprinkler head location.

d. When the renovated space has an open ceiling, the contractor shall provide 1" plugged openings in the branch lines within 12" of the intended future sprinkler head location.

e. The fire sprinkler main riser and floor control valve shall be included in the scope.

f. Critical areas similar to clean rooms and specialty labs may require the inclusion of a 36" long flexible braided stainless-steel hose to accommodate clean, convenient, and non-invasive connection to future sprinkler heads. This item shall be discussed during the programming phase. Otherwise, final connections shall be made via hard-piped double-elbow connection when the building's fire protection system is activated.

g. Fire sprinkler heads shall be installed and connected only after the entire building system meets the code requirements for becoming charged and activated. (Applicable to un-sprinklered or partially sprinklered buildings)

h. The contractor shall provide all pipe supports and seismic restraints to secure the fire protection piping within the spaces under renovation.

i. The contractor shall size the piping to assure that the piping installed within the spaces under renovation can be utilized in the ultimate complete fire sprinkler protection of the building. Basis of design for hydraulic calculations shall be based on actual space usage.

j. The contractor shall pressure test all the fire protection within the spaces under renovation in accordance with NFPA-13. Pressure test to be witnessed by Caltech and Pasadena Fire Department inspector.

k. At the conclusion of the pressure test, purge all pockets from the system and normalize pressure within sprinkler system piping.

2. Fire Protection Design Criteria:

a. The Caltech campus in Pasadena is currently being served from several connections to the city of Pasadena water system. These connections serve both domestic and fire protection demands on campus, with the split between domestic and fire protection services typically occurring at individual building locations. The available water supplies on campus, therefore, are dependent on the water supplies delivered to the campus from the city of

Pasadena public utility water system. The flows and pressures available to deliver the required water supply to individual buildings on campus are dependent upon the Pasadena city flows and pressures as well as the capabilities of the campus water distribution system. Portions of these systems are close to 100 years old.

b. Description of Existing Campus Water Supply System: Caltech is currently being served from several connections to the city of Pasadena water system. These connections serve both domestic and fire protection demands on campus. The main connections occur at San Pasqual Street and Hill Avenue at the east side of campus; San Pasqual and Wilson Avenue on the west side of campus; at Wilson Avenue mid-block between California Boulevard and San Pasqual; and on Wilson at the north end of the Wilson Avenue South parking structure. An additional connection occurs at Del Mar Boulevard and Holliston Street, with a fire main extending down Holliston to the parking structure. This connection was installed to serve the fire protection system demands at the parking structure. Several other connections in California Boulevard have been provided to feed individual buildings at the south end of the campus. Backflow prevention assemblies are typically provided at these connections to the city water mains. The on-site water distribution system piping includes underground piping and piping installed in utility tunnels. Major distribution piping runs east to west across campus. Underground mains originating from the three connections in Wilson Avenue run east to connect into the underground mains in Holliston Avenue and San Pasqual Street at the east side of campus. Although some individual buildings on campus are provided with fire pumps and domestic water pumps, the system as a whole does not have any on-site pumping capacity. Furthermore, since the system serves both domestic and fire protection demands, with the split between domestic and fire service taking place at individual building locations, providing centralized fire pumping capability is not feasible for the current system. Therefore, for both domestic and fire protection water supplies, the campus is dependent on the flows and pressures provided to the site by the city of Pasadena public utility water system. Much of the existing underground piping provided on campus is very old, and some appears to have been installed as part of the original city street improvements in the area, prior to being turned over to Caltech. Some of the piping may even be close to 100 years of age. Piping that has been in service for long periods of time will typically show substantial, or severe, occlusion due to sedimentation and tuberculation in the piping. Such piping would have a substantially decreased internal diameter and would therefore have restricted flow capabilities.

c. City Water Supply: Flow test data performed during 2006 and early 2007 on the city water system in the vicinity of the Caltech campus indicates that static pressures on the system vary from between 75 and 90 psi, depending on the time of day or typical high demand time periods. Such pressure fluctuations in static pressures on the Caltech campus are to be expected. During the fire flow testing performed on-site during this study, static pressures ranged from 68 to 78 psi. A fire flow test performed at the corner of California Boulevard and Wilson Avenue provided the following test data:

Static Pressure:	65–70 psi
Residual Pressure:	68 psi
Flow at residential pressure:	1,285 gpm
Calculated flow at 20 psi:	3,912 gpm

The above test appears to be representative of the water supply available from the city system at various locations in the vicinity of the Caltech campus. The above pressure observations should be used for reference only. **In order to obtain the most current test data, conduct actual tests and confirm the actual water pressure and flow rates.**

d. Condition of Existing Piping: For the San Pasqual and Holliston mains, the calculations indicate a C-factor of around 40. For the piping section between Caltech Hall and Firestone Lab, the C-factor was estimated to be 98. For the Olive Walk piping section, the C-factor was estimated to be 48.

C-FACTOR TABLE

Cast iron, unlined	Mildly Corrosive Water	Moderately Corrosive Water	Severely Corrosive Water
10 years old	110	90	75
15 years old	100	75	65
20 years old	90	65	55
30 years old	80	55	45
50 years old	70	50	40

New cement-lined cast iron pipe has a C-factor of 140. New plastic underground piping has a C-factor of 150. Given the age of some of the existing piping on campus, particularly the piping in San Pasqual Street, Holliston Avenue, and the Olive Walk mains, the C-factor estimations appear to be reasonable.

e. Fire Protection Design Criteria:

1) This standard requires that the fire protection contractor (FPC) shall be a licensed fire protection engineer and shall be a California C-16 contractor in good standing and be the designer and builder of the fire protection system. The FPC shall engineer, fabricate, and install a complete and approved hydraulically designed fire protection system indicated herein and on drawings to approved equal or exceed NFPA 13, 14, 20, and 22 as well as FM Global standards & guidelines, as applicable, and in accordance with City of Pasadena Fire Marshal requirements.

2) All hydraulic calculations shall be based upon the minimum available water flow and pressure available onsite, and the static pressure, flow, and residual pressure used to calculate the system shall be indicated on the plans.

3) Base the piping system layout and arrangement of sprinkler heads upon architectural and structural considerations. Prior to installation of the fire sprinkler mains and branches, coordinate the work with all other trades, including and not limited to electrical conduits, light fixtures, HVAC, plumbing, etc. to ensure there shall be no conflicts and/or discrepancies with other trades. All pipe sizes and number of heads to be used for each area or room shall conform to the requirements of the California Building Code and the National Fire Protection Association Standard 13.

4) Fire Protection Contractor shall obtain current water flow and pressure data. Test data older than 1 year shall be considered invalid.

5) Sprinkler heads shall be positioned in accordance with their UL listing.

6) Sprinkler head spacing shall be as required by NFPA 13 and FM Global, except as follows:

a) In all locations, sprinkler heads shall be equidistant between lights, between wall and lights, between lights and air diffusers, and between wall, lights, and air diffusers.

b) Provide uniform and repetitive patterns for each room. Center sprinkler heads on joints in acoustic tile or center in tiles in order to conform to above.

c) Obtain approval from the architect for the sprinkler head layout and coordinate with other trades.

d) The installed clearance between any sprinkler drops or sprig and the following items shall be at least 3 in. in all directions:

- Permanently attached equipment including their structural supports and bracing; and
- Other distribution systems including their structural supports and bracing.

(as per *ASCE / SEI 7-16 / Ch. 13 – 13.2.3.1 Seismic Design Requirements for Non-Structural Components)*

7) All products, materials, and components used on Caltech projects shall be sourced and manufactured in the U.S.A.

FM Global approved equipment and materials shall be utilized only for their intended purpose.

The primary relevant FM Global standards include but are not necessarily limited to FM Global Property Loss Prevention Data Sheets 2–0, 2–8, 3–26, 3–7, 3–10, 3–11, series 4 standards for special protection systems (e.g., a few are specified below for reference), and series 8 standards (8–9 in particular) for any concentrated storage.

- 2–0 — Installation Guidelines for Automatic Sprinklers
- 2–8 — Earthquake Protection for Water-based Fire Protection Systems
- 3–26 — Fire Protection for Nonstorage Occupancies
- 3–7 — Fire Protection Pumps
- 3–10 — Installation/Maintenance of Private Service Mains and Their Appurtenances
- 3–11 — Flow and Pressure Regulating Devices for Fire Protection Service
- 4–0 — Special Protection Systems
- 4–2 — Water Mist Systems
- 4–9 — Halocarbon and Inert Gas (Clean Agent) Fire Extinguishing Systems
- 8–9 — Storage of Class 1, 2, 3, 4, and Plastic Commodities

3. Electrical Room Fire Suppression:

a. In accordance with (NFPA 13), "sprinkler protection shall be required in electrical equipment rooms," unless all of the following conditions are met:

1) The room is dedicated to electrical equipment only.
2) Only dry-type electrical equipment is used. Coolant oil-filled transformers and similar equipment are prohibited.
3) Equipment is installed in a 2–hour fire-rated enclosure, including protection for penetrations. This requires sealing all penetrations with fire-stopping materials and providing a minimum 90–minute fire-rated door assembly for every doorway into the room.
4) No storage of combustible or non-combustible materials shall be permitted in the electrical rooms.
5) Where sprinklers are installed, non-combustible hoods or shields shall be installed to protect important electrical equipment from sprinkler discharge (NFPA 13–2016, Sec. 8.15.10.2)
6) When electrical equipment rooms are not fire sprinklered, a future fire sprinkler stub pipe, appropriately sized with a butterfly branch isolation valve, shall be installed outside the electrical room without the actual heads and piping inside the room. The design team shall make every attempt to avoid the need for a wet fire sprinkler system in electrical rooms. Only under special circumstances and with Caltech's approval can alternative clean dry systems such as INERGEN, FM-200, or Ansul "Sapphire" be considered. However, due to their high cost, maintenance frequency, and required annual/semi-annual inspection and certification, their use is generally not recommended.
7) In electrical rooms being served by sprinkler systems, provide high temperature sprinkler heads with guards and install drip pans under all sprinkler pipes. Drip pans shall be sloped and piped to the nearest approved plumbing receptor.
8) Unless special provisions are made, no wet utilities other than a dedicated fire sprinkler system shall be installed or go through an electrical room.

4. Pipe and Pipe Fittings:

a. Pipe and fittings shall be sourced and manufactured in the U.S.A. Imported products are unacceptable.

b. Substitution shall be pre-approved by Caltech project manager and mechanical engineer prior to installation.

c. Below grade water service outside of the building to a point within 5'-0" outside the building: Wrapped Class 54, AWWA C104, cement-lined ductile iron with Mega-lug mechanical joints in accordance with NFPA 24; or Class 200 PVC complying with AWWA C900.

d. Above ground and inside the building: Schedule 40, ASTM A53, Grade A or B, seamless or ERW carbon steel pipe with threaded, welded, or cut grooved joints for sizes 2" and below. Fire sprinkler mains may be flexible or rigid couplings. Pipe 2.5" and over can be mechanical flexible grooved couplings.

e. Not permitted: Schedule 10 or below pipes of any material and plastic pipes of any schedule.

f. Welded joints shall be made using factory-fabricated steel welding fittings.

g. Grooved end malleable iron fittings and bolted clamp type malleable iron couplings with rubber sealing gaskets for grooved end pipe with appropriate pressure rating, similar to Victaulic style 75 may be used, except on dry pipe and/or pre-action systems, where couplings shall be provided with rubber "flush seal" gaskets of the same manufacturer as the coupling and intended to be used together.

h. All expansion joint fittings shall be FM Global, UL, and NFPA 13 approved.

i. Unions: Provide ground joint type unions for 2 inch and smaller pipe of galvanized iron with brass seats.

All unions shall be readily accessible and marked for easy identification.

j. Black and hot-dipped zinc-coated (galvanized) welded and seamless steel pipe, ASTM A795:

1) Between Siamese and check valve, ball drip drains, drain, and test piping subject to alternate wetting and drying, test and relief piping, water motor gong piping, and normally dry piping.
2) Fittings and couplings for galvanized pipe shall also be galvanized.

k. Fire sprinkler riser penetrations through the floor slab shall be sleeved 4 inches above finished floor and sealed water-tight to prevent potential flooding of the level below. Daylights or gaps through the floor slab without sleeves are not acceptable. Refer to section 23 00 00 for additional sleeve requirements.

5. Valves: Sourced and manufactured in the U.S.A., listed fire protection valves: FM Global, UL, and ULC listed and approved and State Fire Marshal listed. Provide valves of same manufacturer, including valves furnished with equipment.

a. Gate valves, FM Global, UL, and ULC listed and approved, and State Fire Marshal listed. 2 inches and smaller; bronze body, no copper alloy (brass) allowed containing more than 15% zinc, threaded ends, and 175 psig CWP rating, Nibco T-104-0 (no known equal).

b. Gate valves, FM Global, UL, and ULC listed and approved, and State Fire Marshal listed. 2½ inches and larger, cast iron or ductile iron body, bronze mounted with solid wedge, flanged ends, and 175 psig CWP rating, Nibco F-607-0 (no known equal).

c. Check valves, FM Global, UL, and ULC listed and approved, and State Fire Marshal listed. 2 inches and smaller, screw bonnet, horizontal swing Y pattern, National pipe thread, integral seat, renewable Teflon disc, Nibco KT403W (no known equal). A check valve shall be provided downstream of each floor control valve.

d. Check valves, FM Global, UL, and ULC listed and approved, and State Fire Marshal listed. 2½ inches and larger, swing type, cast iron body, flanged ends, and 175 psig CWP rating, Nibco F908-W (no known equal). A check valve shall be provided downstream of each floor control valve.

e. Check valves: FM Global, UL, and ULC listed and approved, and State Fire Marshal listed. 2½ inches and larger, grooved check valves, Nibco G-917-W.

f. Butterfly valves for floor isolation, FM Global, UL, and ULC listed and approved, and State Fire Marshal listed. 2½ inches and larger, iron body lug or grooved end type, 703SS, shaft-type 316, ductile iron disc, BUNA-N seat — less than 180°F service, EPT seat 180°F to 250°F service, Nibco GD-4765-8N (no known equal).

6. Backflow Preventers — FM Global, UL, USC, ASSE, ULC, and State Fire Marshal listed and approved.

a. Double check with 300 series stainless steel body and stainless steel trim.

1) Deringer Series 20
2) Deringer Series 30
3) Zurn or Wilkins #450 allowed only where the N pattern installation is required for compact fit.
4) No substitutions will be accepted.

b. FEBCO products are not allowed on any Caltech campus projects.

c. Double check back flow assemblies shall be provided with supervisory switch and butterfly valves. Provide detector assemblies only when required by the city of Pasadena.

d. Epoxy coated shutoff valves are not allowed for any backflow preventer assemblies.

e. Provide a copy of the test form to project manager/Facilities operations supervisor prior to connection to water distribution.

7. Main fire protection indicator type control valves:

a. FM Global, UL, and ULC listed and approved, and State Fire Marshal listed. Valve must be installed above ground and provided with internal supervisory switch, Nibco Model 3510 or GD-4765 (no known equal).

8. Sprinkler Heads:

a. Provide FM Global approved and UL listed sprinkler heads by Tyco Fire Products, Viking, Reliable, or approved equal.

b. Standard Upright: Pendant fusible link type, automatic water spray bronze heads with standard plain brass finish located in area without ceilings. Sprinklers shall be selected based upon their availability for the construction features and occupancy conditions. Quick response sprinklers may be selected if desirable and acceptable to the City of Pasadena Fire Marshal, and any other authorities having jurisdiction.

c. Semi-recessed type: Pendant fusible link type semi-recessed automatic spray heads with chrome ceiling escutcheons and head located in area with ceilings. Sprinklers shall be selected based upon their suitability for the construction features and occupancy conditions. Quick response sprinklers may be selected if desirable and acceptable to the City of Pasadena Fire Marshal and any other authorities having jurisdiction.

d. Sidewall Type: Semi-recessed horizontal sidewall type with matching screw-on escutcheon plate and guard. **Finish**: polished chrome or enamel with color as selected by the architect.

e. Concealed type: Installation of concealed sprinklers heads with rubber seals is generally not approved by FM Global and shall be prohibited. In lieu of concealed heads, recessed sprinkler heads with the escutcheons providing

the ceiling seal are recommended. Where the sealed type of concealed sprinklers are installed, it is recommended that all of the seals be checked annually to ensure they are not adhering to the ceiling.

f. All of the above heads shall be with finishes, temperatures ratings, and orifice sizes to meet design requirements.

g. Sprinkler heads installed in locations that are subject to mechanical damage in either upright or pendant position shall have guards or protective covers.

h. All sprinkler head types, finishes, and locations shall be reviewed and approved by the architect and Caltech's representative prior to installation.

i. Provide steel cabinet with additional heads in amounts of 5% to total of each type installed and one wrench for each head type. Mount cabinet inside fire control room.

9. Flow Switches:

a. FM Global, UL, and ULC listed and approved and State Fire Marshal listed, vane-type with automatic recycle retard and DPDT contacts, Potter Electric Model VSR, 24V D.C. with two normally open electrical contacts for connections, specified under Electrical Division 26, to fire alarm and annunciator systems. If system is dry pipe, pre-action, or deluge type, a pressure switch shall be used in lieu of a vane type switch.

10. Valve Supervision Switches:

a. FM Global, UL, and ULC listed and approved and State Fire Marshal listed. Provide, on main fire sprinkler riser gate valve and on all other valves controlling water supplies to fire system, a 24V D.C. electrical switch with one normally open contact that will automatically close when valve is closed; for connection specified in Electrical Division 26 to fire alarm "trouble indicator light."

11. Test and Drain Assembly:

a. Pre-assembled indicating stainless steel quarter turn ball valve arrangement; one handle with dual control to provide positive-stop, positioning for test, drain, and shutoff; self-cleaning sight-glass assembly; visual flow indicator for both alarm test and flow test; UL Listed, AGF Model 2500 (no known equal).

12. Alarm Bells:

a. FM Global, UL, and ULC listed and approved and State Fire Marshal listed, Potter Electric Model PBA 12010, System Sensor SSV120–10, 10–inch diameter, 120 volt AC, or approved equal. The alarm bell should be labeled, "In case of emergency dial 5000."

13. House Valves:

a. FM Global, UL, and ULC listed and approved and State Fire Marshal listed, Potter Roemer or approved equal, polished chrome finish.

14. FM Global, UL, and ULC listed and approved and State Fire Marshal listed, Fire Department and Fire Pump Test Connections:

a. Potter Roemer or approved equal, polished chrome finish.

15. Pre-Action System:

a. FM Global, UL, and ULC listed and approved and State Fire Marshal listed, the system shall be single-interlocked, supervised, pre-action system that utilizes an electrically controlled deluge valve on pneumatically pressurized

automatic sprinkler system. Valve assembly shall be factory assembled similar to Viking Total Pac or approved equal, pre-trimmed, re-wired, and factory tested for quick and easy installation. When practical, compressed air shall be supplied from the campus system. Otherwise, compressed air supply shall be through a direct tankless air compressor and shall be included in the package. All dry piping systems shall be galvanized and designed and installed as per NFPA 13 requirements.

16. Testing:

a. Shall be done in accordance with FM Global and NFPA standards, whichever is more stringent; upon completion and prior to acceptance of the installation, subject the system to a hydrostatic pressure test with no visible leakage. Remove and replace all defects due to materials or workmanship occurring during the test and re-test after corrections have been made. All testing shall be approved by Caltech, FM Global representatives, and City of Pasadena Fire inspector. The contractor shall complete two sets of FM Global's contractor's material and test certificates for underground and two sets of FM Global's contractor's material and test certificates for above ground piping. One set is for Caltech's permanent records and one is for FM Global.

17. Hub Drain Detail:

a. FM Global, UL, and ULC listed and approved and State Fire Marshal listed, shall be applied in all locations. Drain shall be sized to accommodate a full 2–inch flow test for the required duration.

18. Portable ABC Fire Extinguishers:

a. Fire Extinguishers Weighing 40 Pounds or Less: Top may not be more than 60 inches above the floor. Acceptable manufacturer: Amerex or Buckeye 5 lb.

b. Fire Extinguishers Weighing More than 40 Pounds: Top may not be more than 42 inches above the floor.

c. Clearance between the floor and the bottom of the extinguisher must be at least 4 inches.

d. Installation must be ADA and code accessibility compliant.

e. FM Global, UL, and ULC listed and approved and State Fire Marshal listed.

f. Maximum distance to nearest fire extinguisher in any lab should be no more than 50 feet.

19. Portable Class K Fire Extinguishers:

a. Provide for individual fryers exceeding 6 square feet in surface area.

b. FM Global, UL, and ULC listed and approved and State Fire Marshal listed.

20. Commercial Cooking Systems:

a. Provide wet chemical system complying with UL300.

21. For fire protection piping, all expansion joint fittings shall be FM Global approved.

DIVISION 22 – PLUMBING

Plumbing Sustainability Principles:

All projects should achieve indoor water use reduction through the use of high-efficiency fixtures (waterless fixtures are not allowed by Caltech). Outdoor water use reduction should be achieved through proper landscape design, the use of climate adapted species, and reduction or elimination of irrigation. Projects should aim for water use reduction beyond the standards of California's Title 24 and LEED where feasible. Beyond conservation, projects should identify and pursue possible uses of reclaimed water in buildings along with the collection, treatment, and reuse of condensate, wastewater, or stormwater where feasible. Overall, projects should consider the energy-water nexus in design and the impact energy consumption has on water consumption and wastewater generation in Caltech's Central Plant.

All major plumbing systems should be commissioned in compliance with Caltech's Smart Commissioning Program (see Commissioning for additional information).

Existing backflow preventers noted to be removed and dismantled in construction documents shall be salvaged. Clean, package, label, and deliver to Caltech per Division 2, Section 02 41 00 - Demolition specifications. Provide documentation of cleaning.

Section 22 00 00 – Plumbing Systems

1. Design Criteria

a. Refer to Appendix X for Plumbing Fixtures Table.

b. Refer to Appendix X for Plumbing Piping and Valving Requirements.

c. Refer to Appendix XX for Caltech Standard Details.

d. Refer to Appendix XXII for OLAR design requirements.

2. Available Services on Campus:

a. Refer to the campus Centrally Delivered Utilities Specifications Table provided as part of Appendix X for Caltech campus utility information.

b. Caltech can provide campus utility maps showing specific sizes of connections within the tunnel system local to the building site under consideration. This is a general overview of criteria surrounding the plumbing piped services throughout the campus.

c. Design, location, and arrangement of all connections to utility tunnel must be submitted in 3D, in 2D plans, and with dimensioned 2D sections to show all access clearance for the walking route. This is to be submitted for review by the Caltech engineering office with regards to clearance and access. Walk-in access from utility tunnel to the building mechanical room is required.

d. All utility shutdowns for connections to the system are to be performed by Caltech campus operations staff. The contractor shall submit utility shutdown request from at least five (5) working days in advance of proposed shutdown. See Appendix XVI for form.

3. Special / Laboratory Plumbing System Criteria:

a. The following table describes design criteria related to special / laboratory plumbing systems:

Special Plumbing Systems Table			
System	**Static Pressure**	**Max. Pressure Drop**	**Remarks**
Vacuum Systems	26” Hg to 28” Hg Pressures to be confirmed with the PI during programming phase	4” Hg *	Minimum 22” Hg vacuum pressure at the furthest outlet. To be confirmed with the PI during programming phase
Oxygen Systems	50 to 55 psi	5 psi *	
Reverse Osmosis (RO) Water Systems	25 to 50 psi	3 psi / 100 ft. **	RO system equipment shall be supplied by a Caltech approved vendor
Deionized Water Systems (DI) 2 — 18 megohm	85 psi	3 psi / 100 ft. **	Supplied from Caltech Central Plant in utility tunnel
Soft Water Systems	25 to 80 psi	3 psi / 100 ft. **	Softener to be furnished by a Caltech approved vendor
CO2 and Nitrogen (N2)	96 psi	10 psi *	Supplied from central source in utility tunnel. Refer to Section 22 60 00 for current buildings supplied with these services.
Compressed Air Systems:		5 psi *	38º F dew point. When required, provide inline particulate filters and/or air dryer, as necessary. 95 psig air supplied from Caltech Central Plant in utility tunnel
High Pressure Air (HPA)	*30 psi to 95 psi		
Compressed Air (CA)	29 psi and lower		
* From Source to Terminus Under Dynamic Conditions ** For Connection to Equipment			

4. Mechanical Rooms, Equipment Support, and Access:

a. Refer to Division 23 — HVAC Systems for mechanical room and access requirements.

5. Sleeves:

a. Plumbing riser penetrations through the floor slab shall be sleeved 4 inches above finished floor and sealed water-tight to prevent potential flooding of the level below. Daylights or gaps through the floor slab without sleeves are not acceptable. Refer to Division 23 — HVAC Systems for additional sleeve requirements.

b. Pipe penetrations from underground or exterior to interior of the building through concrete walls shall be sleeved and link-sealed.

6. Closeout and O&M Manuals:

a. Contractor shall provide one electronic copy (with each section as a separate file) of the "O&M" manuals and a searchable electronic copy of all as-built CAD files as part of the close-out package. The manufacturers' literature should contain pump performance curves, factory certified equipment performance data sheets, electrical data, maintenance procedures, and performance characteristics.

Section 22 05 00 – General Requirements for Plumbing Systems

22 05 13 Common Motor Requirements for Plumbing Equipment:

1. Motors shall be specified as follows:

PLUMBING MOTOR TABLE		
Motor Size	**Electrical Connections**	**Comments**
1/2 HP or less	120V — 1 Phase — 60 Hz	**Preference:** Direct Drive with a minimum of three-speed controller, or EC Motor
3/4 HP or more	460V — 3 phase — 60 Hz (unless existing available service is 208V / 230V)	**Required:** Premium efficiency, service factor or 1.15 **Preference:** Direct Drive with variable frequency drive

2. All motors shall be suitable for non-overloading operations, regardless of operating conditions and capable of continuous operation at full nameplate NEMA rating standards suitable for load, duty, voltage, frequency, hazard, and for service and location intended. Proof of efficiency must be provided in accordance with ANSI/IEEE 112, Test Method B.

3. Motor bearings shaft grounding: All plumbing equipment related poly-phase motors controlled by pulse width modulation (PWM) variable frequency drives (VFDs) shall be furnished and installed with motor shaft grounding rings in order to eliminate pulse switching caused by high frequency and high voltage changes that result in a capacitive induced shaft voltage. These voltages typically cause bearing failures and substantially decrease bearing life by electrically discharging current through the motor bearings to ground causing pitting and fluting failure. Bearing damage may be mitigated by insulating both bearings or installing shaft grounding brushes to divert the current around the bearing. It should be noted that insulating the motor bearings will not prevent the damage of other shaft connected equipment.

4. General purpose motors to be open drip-proof type, 40°C environment with Class A insulation (50°C temperature rise) and rated for continuous duty under full load. Motors for outdoor service to be totally enclosed fan-cooled (TEFC) epoxy-sealed type.

5. Motor ball bearing shall be rated for a minimum AFBMA L–10 life of 200,000 hours.

6. Couplings for direct drive equipment shall be flexible, self-aligning, non-lubricating type, rated for 125% of load, and shall be totally enclosed with heavy gauge steel guards per OSHA requirements.

7. Variable frequency drives shall incorporate the following:

a) 5% integral line reactors to provide harmonic filtration.
b) LON/BACNET card.
c) 5–year extended warranty parts and labor.
d) Factory startup completed by manufacturer.

e) Three (3) contactor bypass feature on equipment without N+1 redundancy or critical equipment per design.

8. Pump and fan motors larger than 5 HP shall be controlled by VFDs.

9. An early break/base block type disconnect shall be provided between the motor and variable frequency drive.

10. Provide disconnect switch within line of sight to motor (less than 10 feet between motor and VFD).

11. Refer to APPENDIX XXI for EC motor requirements.

22 05 23 General-Duty Valves for Plumbing Piping:

1. Refer to Appendix X for plumbing valve requirements.

22 05 29 Hangers and Supports for Plumbing Piping and Equipment:

1. Refer to Appendix X and applicable requirements in Section 23 05 29 for hangers and support requirements for plumbing piping and equipment.

22 05 48 Vibration and Seismic Controls for Plumbing Piping and Equipment:

1. All plumbing systems shall be designed to seismic design category E.

2. The specification section shall be written such that seismic support and anchorage design of piping is explicitly the sole responsibility of the contractor.

3. Provide seismic bracing per latest applicable codes for all piping systems and plumbing equipment suspended more than 12 inches from the structural support system above.

4. Powder-actuated inserts are not allowed to support any pipe work. With prior written approval from Caltech Planning, Design & Construction, it may be used for supporting sheet metal of no more than 50lbs of pull.

22 05 53 Identification for Plumbing Piping and Equipment:

1. Identify with symbol identification and color-code all piping. Provide directional arrows on all circulating systems separate from and adjacent to each identification. Identification shall conform to ANSI A131.1-1981, Scheme of Identification of Piping Systems (OSHA).

2. All valves shall be identified by a numbered brass tag with hole and brass chain on valve stem or handle. Tag shall be minimum 1.5 inches, and numbers and letters shall be at least 0.22 inches high, stamped into the tag.

3. Piping identification shall be manufactured by “Brady” or “Seton”, “Setmark” system as follows:

a. Pipes $\leq$ 6” outside diameter: Pre-coiled type snap-around labels.

b. Pipes > 6” outside diameter: Flat type snap-around labels with metal ties.

c. Pipe labels with adhesive backs are not acceptable.

4. Piping identification shall be 2–inch letter size for pipe or insulation 3 inches or larger; and 1–inch letter size for pipe or insulation 2½ inches or smaller.

5. All piping exposed or concealed in shafts or above ceilings shall be identified with markers at a distance not to exceed 10’–0” O.C. and shall include arrows showing the direction of the flow.

6. **Underground Plastic Pipe Markers**: Bright colored continuously printed plastic ribbon tape, minimum 6 inch wide by 4 mil thick, manufactured for direct burial service.

7. Refer to Appendix X for additional plumbing identification requirements.

Section 22 07 00 – Plumbing Insulation

22 07 00 General

1. For the purposes of this section, the following definitions will apply:
   a. **Exposed Outdoors:** Any portion that is not fully enclosed within a conditioned space or a shaft/riser.
   b. **Exposed Indoors**: Any portion of piping/ductwork that is not within a shaft. All mechanical room piping and piping exposed to view in conditioned space are considered to be exposed indoors.
   c. **Concealed Indoors**: Any portion of piping that is within a shaft, piping above dropped ceilings with access panels, or within a non-accessible (i.e., gypsum board) wall or ceiling void without access panel.

22 07 19 Plumbing Piping Insulation

1. **Piping exposed to weather**: Materials: ASTM B209 aluminum jacketing, 0.016–inch or 0.032–inch ASJ (all weather service) as applicable to the installation location and internally bounded vapor barrier over the entire surface in contact with the insulation.
   a. **Aluminum Jacketing Thickness**:
      1) 0.016–inch for installation not subject to mechanical damage.
      2) 0.032–inch is required for installation in harsh environments and subject to mechanical damage.
   b. **Finish**: Embossed.
   c. **Joining**: Longitudinal slip joints and 2–inch laps.
   d. **Fittings**: 0.016–inch or 0.032–inch-thick die shaped fitting covers with factory attached protective liner as applicable to installation location; see note 1.a.(1) or 1.a.(2) above for additional information.
   e. **Metal jacket bands**: 3/8–inch wide, 0.015–inch-thick aluminum or 0.010–inch-thick stainless steel.
2. Treatment subject to deterioration due to moisture or humidity is not acceptable.
3. Where piping is concealed and not subject to damage, jacketing will not be required — i.e., within walls and above ceilings.
4. Piping installed inside utility tunnels shall be covered with heavy-duty canvas and Childers CP-52C or approved equal.
5. Sanitary waste and storm drain piping susceptible to condensation shall be insulated with closed-cell type insulation, similar to “ArmaFlex” by ArmaCell.
6. **Pipe Insulation Schedule:**
   a. Provide plumbing piping insulation per “Outline Plumbing Piping Requirements” Excel matrix and California Energy Code. When there is conflict, whichever is more stringent prevails.
   b. Provide the following protective jacket, valve, and fitting covers based on location:

Pipe, Valve, and Fitting Cover Schedule		
Location	**Protective Jacket**	**Notes**
Concealed in Ceiling Voids	None	
Mechanical Rooms	PVC	

Inaccessible Shafts	None	
Accessible Shafts	PVC	
Exposed to Outdoors and within Manholes	Aluminum (see above)	0.016” thickness for installation not subject to mechanical damage 0.032” thickness is required for installation in harsh environments and subject to mechanical damage.

Section 22 10 00 — Plumbing Piping

22 11 16 Domestic and Industrial Water Piping

1. **General**:
   a. Connect the building to a campus water main for normal service. Provide water meter in above-ground vault with full-size, valved bypass, and two (2) full line size backflow devices installed in parallel for redundancy. Meter registers should read in cubic feet.
   b. Coordinate point-of-connection to the campus water main with Facilities Operations & Services.
   c. Minimum cover for piping buried below grade shall be 24 to 36 inches from finished grade.
   d. Provide stand-by water connection from a nearby city main, with provisions for temporary meter to be placed when needed. (Temporary water supply for construction activities.)
   e. All pipe, fittings, valves, etc. that contact potable water for human consumption shall be “lead-free” in accordance with NSF–61 and shall be third party certified.
   f. Meters shall have pulse generators, addressable, and capable of communicating with campus BMS via the JACE.
   g. See Plumbing Fixture Table in Appendix X for meter make and model information.
   h. Domestic and industrial water piping includes (D = domestic) DCW, DHW, DHWR and (I = industrial) ICW, IHW, and IHWR.
   i. **Installation and Anchoring of Underground Service Mains**:
      1) Install concrete anchor blocks or tie-rods on all underground lines at all tees and elbows to prevent movement when under pressure. All tie-rods, clamps, brackets, and bolts shall be stainless steel. In addition, coat metal pipe with heavy duty bitumastic material.
      2) Provide a 6” thick sand bed all around the direct-buried pipes.
   j. **Installation of Above-Ground Piping**:
      1) Run mains as indicated on the drawings; maintain a uniform pitch of 1 inch per 50 feet.
      2) Make allowance for expansion and contraction in the installation of all piping so that a 60° F variation in temperature will not cause stress at any point. Securely anchor where necessary to distribute expansion stresses.
      3) Arrange system for complete drainage with 3/4–inch hose valves at low points.
      4) Anchor all lines and risers as necessary to prevent noise or vibration when water is turned on or off.
      5) Separately valve each branch and riser. Make all such valves accessible with approved type panels.
      6) Balance, vent, and adjust piping to provide circulation to all fixtures and to prevent water hammer.
      7) See Section 22 00 00 for sleeve requirements.
      8) Provide lead-free circulation pump with timer and balancing valve on the return loop of DHWR and IHWR.
   k. **Sterilization of Piping Systems**: Refer to Appendix X.
   l. All unions shall be readily accessible and marked for easy identification. Unions on DHW, DHWR, IHW, and IHWR shall not be covered with insulation.

m. Pressure test domestic and industrial water piping either hydrostatically with water as the testing medium or pneumatically with either compressed air or nitrogen as the testing medium.
   1) Domestic and industrial water pipes less than or equal to 2.5–inch diameter shall be tested using either the hydrostatic or pneumatic method; pipes larger than 2.5–inch diameter shall be tested using a combination of hydrostatic and pneumatic testing using 95% water by volume and 5% compressed air to minimize any potential risks posed by stored energy in compressed air.
   2) System piping and components shall be tested with a pressure of not less than 1.5 times the operating pressure and not less than 100 psig. Test pressure shall be held for a minimum period of 24 hours. Test pressure shall not exceed maximum pressure for any pump, valve, or other component in the system under test.
   3) After pressurizing the system, add a tick mark on pressure gauges indicating starting pressure and time/date of the pressure test along with pictures.
   4) Any observed leaks or drops in pressure shall result in a subsequent repair and re-test of the entire piping system.
   5) Pressure test shall be observed by a Caltech Inspector and signed off in writing.

n. Cross-linked polyethylene (PEX) piping is prohibited unless written authorization is provided by Caltech.

2. <u>Domestic and Industrial Cold-Water Systems:</u>

a. System shall be based on a maximum velocity of 6 feet per second and a minimum allowable pressure loss of 1 psi per 100 feet.
b. Minimum pressure to the most remote fixture or equipment shall be per California Plumbing Code or manufacturer's indicated minimum pressures.
c. Minimum pipe size shall be 3/4 inch except for final connection to lavatories and sinks.
d. Minimum pipe connection size shall match fixture connection size.

3. Domestic and Industrial Hot Water Systems:

a. System shall be based on a maximum velocity of 5 feet per second and a minimum allowable pressure loss of 1 psi per 100 feet.
b. Minimum pressure to the most remote fixture shall be per California Plumbing Code or manufacturer's indicated minimum pressures.
c. Minimum pipe size shall be 3/4 inch except for final connection to lavatories and sinks.
d. Minimum pipe connection size shall match fixture connection size.
e. Hot water delivered from public lavatories and hand sinks shall be limited to a maximum temperature of 120º F.
f. Hot water supply temperature serving food service facilities shall be provided at minimum 140º F, unless point-of-use booster water heaters are provided. Coordinate with the food service consultant and/or equipment vendor.

4. Domestic and Industrial Hot Water Return:

a. System shall be based on a maximum velocity of 5 feet per second and a minimum allowable pressure loss of 1 psi per 100 feet.
b. Minimum pipe size shall be 3/4 inch.
c. Maximum hot water temperature drop for recirculating system shall be 5° F.

22 11 17 Alternate Water Systems for Reuse:

1. Alternate water sources for non-potable water systems shall be considered for all new building construction projects.
2. Water sources may include, but not be limited to: greywater, cooling coil condensate, rainwater, reverse osmosis reject, and municipal recycled water. Water sources may be external or internal to the building.
3. Alternate water uses may include, but not be limited to: water closet and urinal flushing, trap primers for floor drains and floor sinks, cooling tower make-up water, and permanent irrigation.
4. Where alternate non-potable water systems are provided, the design and installation shall be in accordance with the California Plumbing Code.
5. Alternate non-potable water systems shall be based on a maximum velocity of 6 feet per second and a minimum allowable pressure loss of 1 psi per 100 feet.

6. Minimum pressure to the most remote fixture or equipment shall be per California Plumbing Code or manufacturer's indicated minimum pressures.
7. All alternate non-potable water pipe shall be permanently marked to identify that it contains non-potable water by use of non-metallic pipe manufactured with purple dye integral to the material or metallic pipe with purple labels in accordance with the California Plumbing Code.
8. Where alternate non-potable water sources are not approved for the project, the following items shall be provided as a minimum on all new building construction projects:
   a. Non-potable water pipe ("purple pipe") shall be routed to all toilet and urinal flush valves in the building. Supply with domestic cold water on day 1. Flanges for a future water meter and reduced pressure backflow preventer shall be accommodated. A valve and cap shall be available downstream of the future meter and backflow device for switchover to future non-potable water. Size for piping distribution, meter, and backflow device shall be determined by engineer.
   b. A 2" non-potable water pipe shall also be routed, valved, and capped at the entrance to the utility tunnel. A valve and cap shall also be provided in the mechanical room for future connection to non-potable water.
   c. Cooling coil condensate from air handling units and fan coils shall be routed through a clearwater waste system to a central location where future collection and treatment is anticipated. A diverting valve and tee shall be installed for diversion to future collection tank.
   d. An area shall be reserved in a mechanical room for future condensate collection tank(s), water treatment, and water booster pumps. Size shall be determined by the engineer.
   e. A pipe shall be stubbed into the building for any future connection to municipal or utility-provided recycled water for future toilet and urinal flushing. Size shall be determined by the engineer.

22 11 19 Water Piping Specialties

1. **Hose Bibs:**
   a. Hose bibs shall be exposed type for mild climate, threaded with anti-siphon vacuum breaker and anti-contamination wall faucet, brass finish, and with cast iron wheel handle. Vacuum breaker to be certified to ASSE Standard 1011 and as listed by IAPMO.
2. **Water Hammer Arrestors:**
   a. Shall be properly sized and located as per recommendations of Plumbing and Draining Institute (PDI) Standard PDI-WH 201.
   b. Shall comply with ASTM B 88, and Type "K" hard drawn copper body, brass piston, and threaded connector. Seal lubricant to be Federal Food and Drug Administration approved for use in potable water systems.
   c. Normal operating pressure is 35 to 250 psig with a maximum surge pressure not to exceed 1500 psig. Arrestor to be fully guaranteed for the entire system life.
   d. Shall be installed on all fixtures with quick closing valves and all valves that close with flow of fluid on headers serving more than (1) one fixture.
   e. Provide threaded unions, isolation valves, and access panels for all water hammer arrestors.
3. **Trap Primers:**
   a. Trap primers shall be all brass valves with threaded ends and adjustment screw for high or low pressure and shall be located at least 7 inches above the trap being served.
   b. Trap primers shall comply with ASSE 1018 and be adjustable to line pressure.
   c. Provide trap primer distribution unit when serving more than one fixture.
   d. Provide access panel for periodic inspection. Entire installation shall be as recommended by manufacturer.
   e. Inline trap sealer devices shall be allowed in lieu of trap primers for floor sinks, floor drains, and hub drains. Trap sealer shall conform to ASSE 1072 and be equal to SureSeal by RectorSeal, Proset, Zurn, Jay R. Smith, and MIFAB.
4. **Backflow Preventers (Domestic and Industrial Cold-Water Systems):**

a. Backflow preventer shall be of the reduced pressure backflow preventer type, threaded or flanged, lead-free with two independent check valves with intermediate relief valve and supplied with shutoff valves and ball-type test cocks.
b. Provide building backflow preventers set up in duplex parallel arrangement to allow testing without shutdown of water service to building.
c. Provide backflow preventer on all domestic water services to cooling towers and other pieces of mechanical equipment requiring water.
d. Provide piped discharge relief drain piping of type DWV copper from backflow preventer to nearest approved receptor.

5. **Pressure Reducing Valves:**
   a. Pressure reducing valves shall be threaded or flanged, lead-free with integral or independent strainer and low-flow bypass valve.
   b. Install with unions for ease of maintenance and removal.
   c. Provide with inlet and outlet pressure gauges and shutoff valves.

22 11 23 Water Booster Pumps

1. **Water Pressure Booster Pump System (N+1 redundancy):** Booster pumps shall be provided with an N+1 redundancy system, each pump sized for 100% of total demand, completely factory flow tested, variable speed, constant pressure water booster system.

   a. Entire package shall be UL listed.

   b. Pumps: Lead-free, end suction, close-coupled, with bronze impeller and replaceable bronze casing, wear ring, and single mechanical seal.

      1) Manufacturers: Weil Aquatronics, Grundfos, Bell and Gossett, or equal.

   c. Motor: Open drip-proof (ODP), NEMA standard, re-greaseable ball bearings, or REFC as required.

   d. Control panel: Pre-wired and tested, NEMA 1, UL listed, magnetic starters with overload protection, through-the-door disconnect for each motor, hand-off automatic switches, pilot lights, fused motor branches, automatic alternator to select lead lag positions of the main pumps. Control circuit transformer, audible and visual alarm indication and reset button. Include the future pump in the control panel.

   e. Hydro-pneumatic Tank: Vertical, ASME rated with FDA approved bladder, 220–gallon capacity, 125 psig, factory mounted and piped with ASME pressure relief valve.

22 13 00 Sanitary Waste and Vent System:

1. The building sanitary waste and vent shall be sized based on the current California Plumbing Code.

2. Horizontal drainage piping shall have a minimum slope of 2%. When necessary, due to structural conditions, or to meet an existing invert elevation, 1% slope may be used for pipe sized 4 inches and larger upon approval from Caltech.

3. Indirect condensate waste pipes from HVAC cooling coils shall be sized in accordance with Section 23 00 00.

   a. Pipe slope, point of discharge / disposal, and material selection shall minimally comply with the California Mechanical Code, California Plumbing Code, engineering drawings, and specifications.

4. Cleanouts serving the sanitary waste and vent system shall be provided, located, and installed based on the current California Plumbing Code.

5. Pressure test sanitary waste piping hydrostatically with water as the testing medium. Pneumatic testing with either compressed air or nitrogen as the testing medium requires prior approval from Caltech PD&C.

a. System piping and components shall be tested based on the pressures listed below. Test pressure shall be held for a minimum period of 4 hours.
1) Hydrostatic Test: 10–foot head of water except at highest opening.
2) Pneumatic Test: 10 psig, requires prior approval from Caltech PD&C.
b. Pressure test shall be observed by a Caltech Inspector and signed off in writing.
c. After pressurizing system, add a tick mark on pressure gauges indicating starting pressure and time/date of the pressure test along with pictures.
d. Any observed leaks or drops in pressure shall result in a subsequent repair and re-test of the entire piping system.

22 14 00 Storm Drainage System:

1. Roof drainage system shall be sized based on current California Plumbing Code.

2. Overflow roof drains shall be provided for all flat roofs and shall be sized based on the current California Plumbing Code. Overflow drains shall spill at face of curb or at face of building at ±6 inches above finish grade.

3. Sizes shall be based on 3 inches/hour rainfall intensity.

4. Combining storm and overflow is allowed under current California Plumbing Code. This option requires pipe sizing at double the rainfall rate. This option is only allowed after discussion and acceptance by Caltech PD&C.

5. Cleanouts serving the storm drainage system shall be provided, located, and installed based on the current California Plumbing Code.

6. Pressure test storm drain piping hydrostatically with water as the testing medium. Pneumatic testing with either compressed air or nitrogen as the testing medium requires prior approval from Caltech PD&C.

e. System piping and components shall be tested based on the pressures listed below. Test pressure shall be held for a minimum period of 4 hours.
1) Hydrostatic Test: 10–foot head of water except at highest opening.
2) Pneumatic Test: 10 psig, requires prior approval from Caltech PD&C.
f. Pressure test shall be observed by a Caltech Inspector and signed off in writing.
g. After pressurizing system, add a tick mark on pressure gauges indicating starting pressure and time/date of the pressure test along with pictures.
h. Any observed leaks or drops in pressure shall result in a subsequent repair and re-test of the entire piping system.

22 16 00 Natural Gas System:

1. Natural gas systems will be used for major mechanical equipment, labs, kitchen use, and laundry, and shall be sized based on the current California Plumbing Code.

2. An 8-inch water column residual pressure at POC to equipment shall be used. Medium pressure gas will be requested upon determination of the total mechanical and plumbing connected loads.

3. The approved seismic shutoff valve, Little Firefighter AGV, shall be provided on the building gas service.

4. Pressure test natural gas piping pneumatically with air or nitrogen as the testing medium.
   a. System piping components shall be tested with a pressure of not less than 10 psig. Test pressure shall be held for a minimum period of 2 hours.
   b. Pressure test shall be observed by a Caltech Inspector and signed off in writing.
   c. After pressurizing system, add a tick mark on pressure gauges indicating starting pressure and time/date of the pressure test along with pictures.
   d. Any observed leaks or drops in pressure shall result in a subsequent repair and re-test of the entire piping system.
   e. After pressure testing is complete, the entire natural gas system shall be purged with dry nitrogen to eliminate all air, debris, and moisture from the piping before natural gas is introduced into the system.
   f. After successful pressure test and purging have been completed, a leakage test in accordance with NFPA 54 Appendix C shall be performed.

22 17 00 Fuel Oil System:

1. Fuel oil system will be provided for the emergency generator. Size and capacity will be determined based on the number of hours and number of days fuel oil needs to be stored as dictated by electrical requirements. See Section 26 30 00 for generator requirements.

2. Propane storage is not allowed in buildings.
   a. Self-contained torch assemblies are allowed if the container's water capacity does not exceed 2.5 lbs.

Section 22 30 00 – Plumbing Equipment

22 33 00 Electric Domestic and Industrial Water Heaters

1. **Electric Tank Type:** Electric Water heaters shall be of the size, capacity, and recovery required, and shall be ASME glass lined, UL Listed, with insulated steel jacket, drain valve with hose connection, temperature controls, and T&P relief valve piped to nearest approved plumbing receptor.
   a. Provide with the following:
      1) Manufacturer's certification of compliance with current code.
      2) Galvanized sheet metal drain pan piped to nearest approved plumbing receptor.
      3) Water heater stand appropriate for installation location.
      4) Seismic bracing.
      5) Expansion tank sized in accordance with manufacturer's directions.
      6) Circulation pump and associated controls for DHWR pipes.
      7) Lead-free construction on all potable water system components
   b. Temperature and pressure relief valves shall be hard piped to the nearest approved plumbing receptor.

c. Manufacturers: Bradford-White, A. O. Smith, Lochinvar, or equal.

2. Electric Instantaneous Type: Electric instantaneous, point-of-use water heaters shall be sized to match the expected flow rate based on the fixture it is connected to.

a. Provide with the following features:

1) UL listing.
2) Flow activation.
3) Stainless steel coils.
4) Flow control valve.
5) Tank or tankless type.
6) Lead-free construction on all potable water system components.

b. Temperature and pressure relief valves shall be hard piped to the nearest approved plumbing receptor.

c. Manufacturer: Chronomite, Eemax, or equal.

22 34 00 Gas-Fired Domestic and Industrial Water Heaters

1. Gas-Fired Tank Type: Ultra-low NOx gas-fired water heaters shall be of size, capacity, and recovery required.

a. Provide with the following:

1) ASME glass lining.
2) UL listing.
3) Complete with insulated steel jacket.
4) Drain valve with hose connection.
5) Draft diverter.
6) Temperature controls.
7) Heater gas cock.
8) Pilot gas cock.
9) 100% safety pilot.
10) Shall be AGA approved.
11) Efficiency shall be 85% or greater.
12) Provided with a T&P relief valve piped to nearest approved plumbing receptor.
13) Galvanized sheet metal drain pan and water heater stand appropriate for the installation location.
14) Seismic bracing.
15) Expansion tank sized in accordance with manufacturer's directions.
16) Circulation pump and associated controls for DHWR pipes.
17) Lead-free construction on all potable water system components.

b. Temperature and pressure relief valves shall be hard piped to the nearest approved plumbing receptor.

c. Manufacturer: Bradford-White, A. O. Smith, Lochinvar, or equal.

2. Gas-Fired Domestic (Industrial) Hot Water Boilers: Domestic hot water boilers shall be ultra-low NOx, copper fin tube boilers for use with a separate DHW storage tank, suitable for indoor or outdoor installation of the size, capacity, and recovery required.

a. Boilers shall be:

1) Non-condensing.
2) Minimum 84% efficient.
3) Provided with safety/temperature controls.
4) Provided with T&P relief valve piped to nearest approved plumbing receptor.
5) Provided with an integral circulating pump.
6) Manufacturer: Raypak, Lochinvar, or equal.

b. Storage tank shall be:

1) ASME glass lined.
2) Insulated.
3) Vertical or horizontal configuration.
4) Provided with manhole and tappings.
5) Provided with drain valve with hose connection.

c. System shall be provided with circulation pump and associated controls for hot water return system.

d. Lead-free construction on all potable water system components

e. Temperature and pressure relief valves shall be hard piped to the nearest approved plumbing receptor.

3. **Gas-Fired Tankless (Condensing Water Heaters – for domestic residential applications only):** Tankless gas-fired condensing water heaters shall be suitable for indoor or outdoor installation, of the size, capacity, and recovery required. (To be specified only when authorized by Caltech PM/PE).

a. Provide with the following:

1) Compliance with SCAQMD requirements.
2) Minimum 94% energy efficiency.
3) Electronic controls.
4) Third-party listing.
5) Digital display for temperature and maintenance codes.
6) Venting kits and condensate neutralization.
7) Circulation pump and associated controls for DHWR pipes.
8) Lead-free construction on all potable water system components.

b. Manufacturer: Rheem, Bradford White, Noritz, Bosch, Takagi, or equal.

22 35 00 Domestic and Industrial Water Heat Exchangers

1. Heat exchangers for domestic hot water shall be:

a. Steam-to-water, semi-instantaneous type

b. Double-walled required for domestic application. Single wall is acceptable for industrial application.

c. Copper u-tube bundle with appropriate non-ferrous waterside tube sheet, baffles, and tie rods

d. HX shall be ASME rated for 150 psi and 300ºF service.

e. HX shall be equipped with temperature and safety controls.

f. Temperature and pressure relief valves shall be hard piped to the nearest approved plumbing receptor.

g. Manufacturer: Cemline, AERCO, A.O. Smith, Thrush, or equal.

Section 22 40 00 —Plumbing Fixtures

22 40 00 Plumbing Fixtures

1. **Caltech Preferred Vendor List for Plumbing Fixtures:** See also individual sections of the guidelines for more details on model numbers. Refer to Appendix X

2. Emergency eyewash and emergency showers shall be field tested prior to occupancy.

Section 22 60 00 — Laboratory Plumbing Systems

22 61 00 Compressed Air Systems for Laboratory Facilities:

1. **Air Compressor System (N+1 redundancy):**

   a. **Unit shall be designed and built as follows**:

   1) Equipment compressed air system shall consist of multiple air-cooled, oil-less, reciprocating or scroll air compressors, and a control module base, all part of a pre-assembled package. The control module base shall be constructed of a heavy gauge structural steel frame with forklift slots.

   2) The following components shall be mounted on the control module base:

   a) Air receiver
   b) Air dryer
   c) Control panel
   d) Compressed air filters
   e) Pressure reducing valve station
   f) Test port
   g) Main system shutoff valve

   3) The control module base shall have the same footprint dimensions as the base mounted compressors. Each of the components shall be designed to fit through a standard 36–inch doorway.

   4) The package shall require only two plumbing connections (intake and discharge) and two electrical connections (one to the control panel and one to the air dryers).

   5) System to be factory tested and disassembled for shipping and installation at job site.

   6) All piping shall be capped or plugged to prevent contamination during shipment and installation.

   7) Manufacturers: Kaeser, Ingersoll Rand, or equal.

22 62 00 Vacuum for Laboratory Facilities

1. **Laboratory Grade Vacuum Pump System (N+1 redundancy):**

   a. **Unit shall be designed and built as follows**:

   1) Vacuum pump system shall consist of multiple fan-cooled, totally enclosed motor, automatic start/stop, duplex reciprocating or rotary vane vacuum pumps with interconnecting piping. Low oil level shutdown switch, vacuum switch, magnetic starters, disconnect switch, laboratory purge valves for chemistry division labs, alternators, hour meter, manual reset button and control panel all skid-mounted and factory assembled on a vertical or horizontal tank. Tank shall be 200 psig working pressure.

   2) The skid-mounted package shall fit through a standard 36–inch doorway.

   3) System shall be factory assembled and tested.

   4) All piping shall be capped or plugged to prevent contamination during shipment and installation.

   5) Vacuum exhaust shall be sized based on manufacturer recommendations. Exhaust pipe shall be routed separately out of building to exterior.

   6) Pump capacity: Shall be determined during programming phase of the project.

7) Manufacturers: Busch, Quincy, Welsh, or Caltech approved equal.

2. Point-of-Use Laboratory Grade Vacuum Pump System

a. Local vacuum pumps may be required when specific research requires deep vacuum (27" to 29" Hg). Locate vacuum pumps in fume hood base cabinet or dedicated ventilated vacuum pump cabinet in casework.

b. Unit shall be diaphragm type pump.

c. Laboratory vacuum exhaust shall have an inline mist eliminator and/or oil trap before tying into building exhaust to prevent oil entrainment in ductwork.

22 63 00 Gas Systems for Laboratory Facilities

1. Pipe and System:

a. Nitrogen (N2) is a centrally distributed gas and a chargeable utility gas from liquid nitrogen bulk tank boil-off. For nitrogen, a 2.5–inch diameter type "L" copper pipe main header distributes nitrogen gas to certain laboratory buildings at 100 psig and about 95˚ F ±5˚F.

b. Carbon dioxide (CO2) is a centrally distributed gas and a chargeable utility gas from a central bulk tank. A 2" diameter type "L" copper pipe main header distributes CO2 gas to certain buildings at 100 psig.

c. Currently, the following buildings are being provided with lab specialty gases using a branch line and dedicated isolation valve:

1) Keck Lab (N2 only)
2) Steele Lab (N2 only)
3) Jorgensen Lab (N2 only)
4) Watson Lab (N2 only)
5) Schlinger Lab (N2 only)
6) North Mudd Lab (N2 only)
7) Linde+Lab (N2 only)
8) Moore Lab (N2 only)
9) Beckman Institute (N2 only)
10) Spalding Lab (N2 only)
11) Gates-Thomas Lab (N2 only)
12) Synchrotron (N2 only)
13) Linde Hall (N2 only)
15) Noyes Lab (N2 only)
16) Church Lab (N2 only)
17) Chen Neuroscience Research Building (N2 and CO2)
18) Broad Lab (CO2)
19) Braun Lab (CO2)

d. Additional lab buildings will be added to the nitrogen or carbon dioxide distribution network based on demand analysis.

e. Caltech Facilities is responsible for the selection, installation, operation, and maintenance of the main central building gas mass flow meter(s).

e. Each project will be responsible for the selection, installation, and maintenance of laboratory gas mass flow meters. Campus mechanical engineer and Facilities personnel will provide assistance with meter selection and installation.

f. In order to maintain reliable readings, each mass flow meter requires an annual calibration by a certified factory trained technician. Calibration certification and related documentation shall be included with each mass flow meter.

g. Pressure test laboratory gas and vacuum piping pneumatically with nitrogen as the testing medium.

1) System piping and components shall be tested with a pressure of not less than 1.5 times the operating pressure but not less than 150 psig. Test pressure shall be held for a minimum period of 24 hours. Test pressure shall not exceed maximum pressure for any valve or other component in the system under test.
2) After pressurizing system, add a tick mark on pressure gauges indicating starting pressure and time/date of the pressure test along with pictures.
3) Initial and final pressure readings shall be observed and recorded by a Caltech Inspector.
4) Any observed leaks or drops in pressure shall result in a subsequent repair and re-test of the entire piping system.
5) Facilities management shall observe and inspect each mass flow meter system after installation is completed to ensure proper and leak-free operation.

2. Non-reactive lab gas Mass Flow Meter Installation Requirements

a. Reference Nitrogen Meter Piping Diagram in Appendix XX.

b. Mass flow meters shall be provided with Modbus RTU–485 communications protocol.

3. Mass Flow Meter Testing and Record Retention Requirements:

a. The following installation information shall be provided to PD&C and Facilities Management as part of the close-out package:

1) Inspection and test records
2) Date of line installed
3) Date of the mass flow meter installation
4) Operational and final approval documentation
5) O&M manual

b. The following mass flow meter testing and certification records shall be provided to PD&C and Facilities Management as part of the close-out package:

1) Mass flow meter serial number and model
2) Mass flow meter specifications and measuring ranges
3) Factory calibration certification
4) Campus inspector and/or plumbing shop records of project inspection
5) Pressure test report
6) Mass flow meter onsite function and calibration tests
7) Factory recommended service requirements

22 66 53 Acid Waste and Vent System:

1. The building acid waste and vent system shall be sized similar to the sanitary waste and vent system.

2. Horizontal drainage piping shall have a minimum slope of 2%. When necessary, due to structural conditions, or to meet an existing invert elevation, 1% slope may be used for pipe sized 4 inches and larger upon approval from Caltech.

3. The pipe materials shall be evaluated based on the type and temperature of the anticipated wastes being discharged.

4. Cleanouts serving acid waste and vent systems shall be provided, located, and installed based on the current California Plumbing Code. Cleanout material shall be appropriate to handle the anticipated wastes being discharged.

5. Pressure test acid waste system piping hydrostatically with water as the testing medium. Pneumatic testing with either compressed air or nitrogen as the testing medium requires prior approval from Caltech PD&C.

a. System piping and components shall be tested based on the pressures listed below. Test pressure shall be held for a minimum period of 4 hours.
  1) Hydrostatic Test: 10–foot head of water except at highest opening.
  2) Pneumatic Test: 10 psig, requires prior approval from Caltech PD&C.

b. Pressure test shall be observed by a Caltech Inspector and signed off in writing.

c. After pressurizing system, add a tick mark on pressure gauges indicating starting pressure and time/date of the pressure test along with pictures.

d. Any observed leaks or drops in pressure shall result in a subsequent repair and re-test of the entire piping system.

DIVISION 23 – HEATING, VENTILATING & AIR CONDITIONING (HVAC)

HVAC Sustainability Principles:

Energy modeling should be performed to support life-cycle cost evaluation during early design (schematic design and design development) to ensure that the HVAC system selected for the project meets the project energy target/goal. Energy models should compare several HVAC system options based on the project program, budget, scope, and schedule requirements. HVAC system options to be evaluated should be reviewed with Caltech. The primary purpose of the energy modeling shall be to identify the most energy efficient HVAC system option, as well as the HVAC system option that provides the lowest life-cycle cost.

Overall, all projects should maximize energy efficiency and HVAC system performance to the greatest extent possible given the project scope, budget, and schedule constraints. More specifically, projects should comply with the following environmental quality and energy requirements:

- **a.** Utilization of air side and/or water side economizer cycles to reduce mechanical cooling and heating
- **b.** Implementation of variable frequency drives or EC motors to achieve a meaningful turn-down and subsequent reduction in fan power energy
- **c.** Implementation of direct digital controls (DDC) and addressability for key HVAC system components
- **d.** Implementation of system pressure and temperature resets
- **e.** Implementation of variable flow systems versus constant flow systems
- **f.** Utilization of dedicated outdoor air units and displacement ventilation, where feasible
- **g.** Utilization of terminal cooling and heating systems (e.g., chilled beams, radiant panels, etc.) versus all air systems
- **h.** Utilization of appropriate filter media (MERV8 + MERV13 or 14 rating per OPR) to minimize particulate count for the specific environment
- **i.** When required, utilize UVC irradiation lights of appropriate intensity to control growth of biological matter in the specific environment
- **j.** Utilization of natural ventilation for non-laboratory environments consistent with energy efficiency goals
- **k.** Maintenance of ideal indoor temperature and relative humidity
- **l.** Minimization of noise and vibration
- **m.** Utilization of occupancy sensors and unoccupied setback mode of operation
- **n.** Utilization of carbon dioxide sensors (CO2) and demand-based ventilation

All major HVAC systems should be commissioned in compliance with Caltech's Smart Commissioning Program (see Commissioning).

Existing backflow preventers noted to be removed and dismantled in construction documents shall be salvaged. Clean, package, label, and deliver to Caltech per Division 2, Section 02 41 00 - Demolition specifications. Provide documentation of cleaning.

Section 23 00 00 – HVAC Systems

1. **Design Criteria:**

a. The following design criteria are to be followed whenever possible, except where there is a conflict with any specific building program, in which case the building program shall prevail. For any items not mentioned either in the design

guidelines or project program, the consulting engineer shall use their best judgment in accordance with modern practice and consultation with Caltech project manager and Caltech mechanical engineer.

HVAC DESIGN CRITERIA			
Season	**Outdoor Temp**	**Indoor Temperature and relative humidity**	**Notes**
Summer	107º F dry bulb	72º ±2º F dry bulb	To be specified during pre-design phase as part of bridging documents
	72º F wet bulb	50% ±5% RH	
Winter	35º F	72º ±2º F	
Winter Humidifier Design	35º F dry bulb 2% RH	N/A	The noted outdoor design conditions shall be utilized for sizing of all humidifiers
Comments	California Energy Code may override these preferences	The most current ASHRAE Fundamentals guide may be consulted for recommended internal temp and %RH setpoints for non-laboratory spaces	Temp T and %RH for labs and specialized rooms shall be determined during the programming phase

b. All habitable areas in the building are to be air conditioned from central air handling units located inside mechanical rooms away from occupied spaces. Mechanical rooms may be located on the roof or other areas exposed to the elements.

c. Where spot cooling of normally unoccupied areas is necessary, it is acceptable to use dedicated fan coil units or computer room units. All other uses of these devices require the explicit approval of Caltech.

d. HVAC for Telecommunication Spaces (TS): The following requirements shall apply to the cooling of network/data closets. Refer to Section 27 00 00 for additional requirements.

1) The source of cooling shall be the campus' chilled water feeding dedicated AHU(s) or FCU(s), cooling-only with associated temperature control valve actuator failure position of fail-open (i.e., spring return).

2) Where practical, all HVAC components shall be located outside of the room.

3) Air distribution components (ductwork, grilles, registers, etc.) shall not be located above equipment racks. When located above cable tray within the room, a minimum of 2 feet clearance above the cable tray shall be maintained.

4) Supply air delivered to the space shall be provided with a minimum MERV13 filtration to mitigate any dust issues.

5) The space shall be positively pressurized.

6) Thermostats, temperature sensors/transmitters, etc. shall communicate with the Building Automation System (BAS) via the JACE for remote monitoring and alarming purposes.

7) Hydronic piping, including cold condensate, shall not be located within the room.

i. When the AHU or FCU is required to be located inside the room, all piping shall be routed such that no piping is located directly above IMSS equipment. Piping installed within the room shall be provided with

a continuous drain pan that matches the extent of the piping. **Approval by Caltech IMSS shall be required prior to locating piping, ductwork, or HVAC equipment within telecommunication spaces.**

e. All heating and cooling load calculation assumptions must be documented with the source explicitly referenced. The following shall be presented to Caltech for internal review:
  1) U-values and solar heat gain coefficients (SHGC) for all building envelope components
  2) Internal heat gains assumed for lighting, equipment, plug loads, and occupants (based on density) for each room
  3) Ventilation rates by room, including any special pressurization relationships
  4) Special heat loads generated by equipment (as noted in the building program or obtained from other consultants)

f. Direct expansion (DX) cooling shall not be utilized unless approved by the Caltech project manager. When provided, exterior air-cooled condensing units, located on grade or on the roof, shall be designed for an outdoor ambient temperature of 130°F.

g. The first sheet of the mechanical construction drawing set shall state the building design heating and cooling loads and design flow rates for steam, heating hot water, and chilled water.

h. Refer to Appendix XI for General Mechanical requirements.

i. Refer to Appendix XII for Mechanical and HVAC Hydronic Piping requirements.

j. Refer to Appendix XX for Caltech Standard Details.

k. Refer to Appendix XXII for OLAR design requirements.

l. Condensate waste pipes from HVAC cooling coils shall be sized in accordance with the equipment capacity as follows:
  1) Minimum condensate waste pipe size shall be sized per the California Mechanical Code and California Plumbing Code, but not less than 1–inch in size and not smaller than the equipment outlet size.
  2) Pipe slope, point of discharge / disposal, and material selection shall minimally comply with the California Mechanical Code, California Plumbing Code, engineering drawings, and specifications.

MINIMUM CONDENSATE PIPE SIZE	
EQUIPMENT CAPACITY IN TONS OF REFRIGERATION	MINIMUM CONDENSATE PIPE DIAMETER (INCHES)
UP TO 40	1
41 – 90	1¼
91 – 125	1½
126 – 250	2

m. Roof curb minimum height requirements shall be as follows:
  1) Rooftop penetration curb for pipes and ducts: Minimum 8 inches tall
  2) Rooftop equipment curb: Minimum 14 inches tall

2. Available Services on Campus:

a. Refer to the campus Utilities Table provided as part of Appendix XII for Caltech campus utility information.

b. Caltech can provide campus utility maps showing specific sizes of connections within the tunnel system local to the building site under consideration. This is a general overview of criteria surrounding the plumbing piped services throughout the campus.

c. Design, location, and arrangement of all connections to utility tunnel must be submitted in 3D, in 2D plans, and with dimensioned 2D sections to show all access clearance for the walking route. This is to be submitted for review

by the Caltech engineering office with regards to clearance and access. Walk-in access from utility tunnel to the building mechanical room is required.

d. All utility shutdowns for connections to the system are to be performed by Caltech campus operations staff. The contractor shall submit utility shutdown request form at least five (5) working days in advance of proposed shutdown. See Appendix XVI for form.

3. Mechanical Rooms, Equipment Support, and Access:

a. For mechanical rooms, provide the following:

1) Dedicated controlled access to mechanical rooms. These must be separate from electrical rooms and any laboratory-support equipment. HVAC and plumbing equipment may share the same mechanical room.
2) Mechanical rooms shall be located away from acoustically sensitive zones. If not possible, meet the recommendations for acoustical isolation from an acoustical engineer.
3) Provide stainless steel floor sink(s) and drains with trap primers or trap seals in mechanical rooms with heavy duty load rated grates.
4) Provide a minimum clearance of 30 inches around all equipment requiring maintenance.
5) Locate equipment so that parts requiring maintenance may be removed without shutting down or interfering with operation of other equipment (dampers, actuators, filters, tube-bundles, motor armatures, heating/cooling coils, etc.).
6) Sleeve all pipes through the floor (see requirements for **sleeves** below) and concrete walls.
7) Provide cooling and/or ventilation independent from the building systems and adjacent spaces.
8) Provide adequate lighting unobstructed by ducts or piping.
9) Ensure that all parts of the system have not less than 6’-6” headroom for both approach and working areas.
10) All air plenum access doors to open against static pressure.
11) All moving parts must be visible.
12) Ladder access is acceptable only for small, light, or infrequently serviced equipment and must be direct, via an access panel, but not requiring the maintenance person to go into a crawl space. Coordinate stairs, gratings, and ladders for equipment access with structural and architectural drawings. All equipment requiring portable ladder access shall require written approval from Caltech and must explicitly be identified in the drawing set through a symbol or annotation. Provide hoist beams and dedicated attachment points for any equipment over 50 lbs. and located 6’ or higher above the floor.
13) For non-roof-mounted equipment, provide a minimum of 4” thick concrete bases without dirt-catching pockets to facilitate housekeeping. Wherever located, bases should be engineered by a structural engineer.
14) Concrete pads for roof-mounted equipment shall be a minimum of 4” above finished roofing system (i.e., above insulation and roofing material). Wherever located, bases should be engineered by a structural engineer.
15) Acoustical engineer shall select engineered vibration mounts to dampen the dominant frequency for heavy or pulsating equipment and shall select springs or rubber-in-shear for attenuation in the higher frequencies for light equipment.
16) Vibration isolation springs or rails shall comply with requirements of seismic zone 4 for vertical and lateral restraint.
17) The following locations are requirements for mechanical spaces:

MECHANICAL SPACE REQUIREMENTS TABLE		
Preferred Mechanical Room Location	At Slab-On-Grade	Ensure areaway, doors, etc. are sized to allow equipment removal. Provide walk-in access from the utility tunnel and from a building corridor.
Secondary Location	Above Occupied Space	Surround the room with a 6–inch curb, a 2–inch fiber cant, and waterproof the floor as described in Section 07 50 00 - Roofing and Waterproofing General Requirements. Obtain acoustical engineering recommendations to mitigate transmission of noise and vibration. Ensure doors or hatchways are sized to permit removal of major equipment. Provide walk-in access from a building corridor.
Outdoor Locations Not Normally Seen by Public		Use pre-manufactured roof support and roof curb systems as designed by a professional structural engineer licensed in the state of California. Incorporate vibration isolation as recommended by the acoustical engineer.

18) Provide electrical outlet and industrial water hose bib within 6 feet of AHU.

b. For major equipment outside of mechanical rooms (i.e., roof equipment wells, etc.) provide the following:

1) Ensure that all parts of the system have nominally 8'-0" clearance, but not less than 6'-6" headroom, for both approach and working areas.

2) Provide permanent stair access. Permanent ship's ladder access is acceptable only for small, light (less than 50 lbs), or infrequently serviced equipment and must be direct, via an access panel but not requiring the maintenance person to go into a crawl space. A written Caltech approval for this feature shall be required.

3) Provide a minimum 22"x22" access panel or access door to pipe and duct spaces at each floor. Enclosures shall meet fire separation and safety requirements of the applicable codes as set forth by UBC, UMC, NFPA, California Fire Marshal, and all other authorities having jurisdiction.

4) Provide ceiling and wall-mounted access panels to all equipment requiring adjustment, replacement, or maintenance. Access includes but is not limited to, fire damper actuator, hydronic valves, trap primers, VAV controllers and dampers, combination fire/smoke dampers, control devices, actuators, duct access doors, and manual volume dampers. Locations shall be shown on shop drawings and shall be approved by architect/engineer prior to framing and installation of the panel. Whenever possible, locate panels in such a way to utilize single panel to access multiple devices. Equipment shall be within easy reach from the openings without requiring personnel to stretch or leave access platform. When permissible, access panels shall be at least 28 inches by 28 inches clear inside dimensions. Where components are located above T-bar ceilings, careful consideration must be given to the unit location to accommodate convenient access.

5) Provide a minimum 14"x14" ceiling access panel for components requiring only adjustment (e.g., manual volume dampers).

6) Provide electrical outlet and industrial water hose bib within 6 feet of AHU.

c. Coordination: Coordinate the following with architectural considerations:

1) Roof curbs.

2) Machinery foundations and supports.

3) Stairs, catwalks, platforms, and gratings for access to main machinery (i.e., AHUs, large EFs) — reliance on portable ladders is not acceptable.
4) Wall openings for ventilation louvers.
5) Sumps, trenches, and tunnels with necessary covers and gratings.
6) Louvered or undercut doors.
7) Routes for fume hood ducts (present and future) and vertical pipe risers, which must remain exposed and will require access.
8) Access doors to valves, dampers, and the like.
9) Adequate space for horizontal and vertical duct and pipe installation.
10) Vertical shafts and chases without horizontal offset.
11) Vertical shaft termination in or conveniently close to mechanical rooms.
12) Flashing and counterflashing.
13) Roof tie-offs for fall protection.

4. Sleeves:

a. Provide the following:

1) Sleeves are required for all piping passing through all structural concrete and exterior wall construction. In above-grade construction, provide sleeves in the concrete floor, located so that all riser penetrations fall within the designated pipe chase. Unless noted elsewhere, top of sleeve shall be set a minimum of 4 inches above finished floor to prevent accidental leakage of liquid spills through the slab to the floor below. The sleeve shall either be provided with an integral water-stop or bonded to the concrete slab by means of epoxy to provide a water-tight seal. Daylights or gaps through the floor slab without sleeves are not acceptable.
2) Sleeves to have 7/32–inch minimum thickness.
3) Sleeves passing through floors in occupied zones shall project a minimum of 2 inches above the finished floor slab and be sealed watertight.
4) Sleeves passing through mechanical room floors shall extend a minimum of 4 inches above finished floor and have proper flashing, and sealed water-tight.
5) Provide a minimum of ½–inch clearance around the outer edge of full-thickness pipe insulation (if insulated) or pipe exposed outer face (if not insulated).

b. At 100% design development, provide Caltech a coordinated set of plans and exterior structural wall elevations showing all required sleeves. Additionally, on the same drawings, locate and identify spare sleeves equal in number and size to the required sleeves and locate them reasonably distributed horizontally and vertically throughout the building. These documents will be reviewed to determine the extent of structural and architectural coordination as well as provision for future flexibility.

5. Closeout and O&M Manuals:

a. See Section 23 05 93 for the requirements of the testing, adjusting, and balancing procedures required to be performed prior to final acceptance by Caltech project manager.

b. After all HVAC work has been tested, commissioned, and approved, the contractor shall thoroughly clean all parts of the equipment installed as part of the project. Air handlers shall contain clean filters. Piping strainers shall be clean. Bearings shall be lubed with appropriate type of grease. Exposed parts shall be cleaned of overspray, plaster, grease, oil, and other materials. Exposed rough metalwork shall be brushed down to remove rust and sharp edges and surface shall be prepared to receive painter's finish, when applicable.

c. Contractor shall provide one electronic copy (with each section as a separate file) of the O&M manuals, a searchable electronic copy of all as-built CAD files, DDC control diagrams, sequence of operation, and the final air

and water balance report as part of the close-out package. The manufacturers' literature should contain pump and fan performance curves, factory certified heating and cooling coil performance data sheets, temperature control valve specifications, CAV/VAV terminal air unit performance, sound attenuation, electrical data, maintenance procedures, and performance characteristics. Refer to Appendix II, Submittal Register for detailed list of all required closeout documents.

d. Spare parts at handover/turn-on time shall include a fresh set of filters in each filter bank.

6. **Caltech Preferred Vendor List:** For major equipment. See also individual sections for more details on model numbers.

Equipment Type	Caltech Acceptable Manufacturers
Pumps	Thrush, Aurora, Bell & Gossett, Armstrong
Expansion Tanks	Wesler, Armstrong, Bell & Gossett, Amtrol
Air Separators	Armstrong, Bell & Gossett, Amtrol
Heat Exchangers	Thrush, Armstrong, Bell & Gossett, Alpha-Laval
Steam Traps	Armstrong, ITT Hoffman
Steam Pressure Reducing Valves	Armstrong GP-1000, ITT Hoffman
Steam Pressure Relief Valves	Armstrong, ITT Hoffman, Kunkle Knuckle
Steam Condensate Recovery Pumps-	Armstrong, ITT Hoffman, Shipco
Computer Room Air Conditioning Units	Liebert, Compu-Aire
Air Handling Units	Thermal, Alliance, Dynamic Air Technology, Energy Labs
Fans (Non-Product Conveying Hood)	Loren Cook, New York Blower, Twin City
Fans for Chemical Fume Hood Exhaust	Strobic, MK Plastics, New York Blower
VAV Boxes	Titus, Krueger, Nailor, Envirotec
Volume Dampers	Ruskin, Greenheck
Smoke Fire Dampers	Ruskin, Greenheck, United Enertech, Pottorff
Fan Coil Units for Mechanical Rooms	Thermal TH Series, Multi-Aqua, Dynamic Air Technology
Diffusers	Titus, Price, Nailor, Krueger
Temperature Control Valves	Johnson Controls (Pneumatic), Siemens (electric), Belimo
Shutoff Valves	Nibco
Strainers	Watts, NIBCO
Lab Supply Air and Exhaust Air Valves	AccuValve
Variable Frequency Drives w/BACNET or LONWORKS Card	ABB
Motors	General Electric, Baldor, Westinghouse, US Motors, Toshiba
Fan Powered HEPA Filter	Flanders, EnviroTech, Greenheck

Section 23 05 00 – General Requirements for HVAC Systems

23 05 13 Common Motor Requirements for HVAC Equipment:

1. Motors shall be specified as follows:

HVAC MOTOR TABLE		
Motor Size	**Electrical Connections**	**Comments**

1/2 HP or less	120V — 1 Phase — 60 Hz	**Preference:** Direct drive with a minimum of three-speed controller for balancing purposes, or EC Motor
3/4 HP or more	460V — 3 phase — 60 Hz (unless existing available service is 208V / 230V)	**Required:** Premium efficiency, service factor or 1.15 **Preference:** Direct drive with variable frequency drive

2. All motors shall be suitable for non-overloading operations, regardless of operating conditions, and capable of continuous operation at full nameplate NEMA rating standards suitable for load, duty, voltage, frequency, hazard, and for service and location intended. Proof of efficiency must be provided in accordance with ANSI/IEEE 112, Test Method B.

3. Motor bearings shaft grounding: All HVAC related poly-phase motors controlled by pulse width modulation (PWM) variable frequency drives (VFDs) shall be furnished and installed with motor shaft grounding rings in order to eliminate pulse switching caused by high frequency and high voltage changes that result in a capacitive induced shaft voltage. These voltages typically cause bearing failures and substantially decrease bearing life by electrically discharging current through the motor bearings to ground causing pitting and fluting failure. Bearing damage may be mitigated by insulating both bearings or installing shaft grounding brushes to divert the current around the bearing. It should be noted that insulating the motor bearings will not prevent the damage of other shaft connected equipment.

4. General purpose motors to be open drip-proof type, 40°C environment with Class A insulation (50°C temperature rise), and rated for continuous duty under full load. Motors for outdoor service or in wet airstreams to be totally enclosed fan-cooled (TEFC) epoxy-sealed type.

5. Motor ball bearing shall be rated for a minimum AFBMA L–10 life of 200,000 hours.

6. Couplings for direct drive equipment shall be flexible, self-aligning, non-lubricating type, rated for 125% of load, and shall be totally enclosed with heavy gauge steel guards per OSHA requirements.

7. Where belt drives are the only available option, provide evidence of such to Caltech and specify OSHA belt guards, motor slide rails, and TAB responsibility for final belt adjustment for balancing.

8. Variable frequency drives shall incorporate the following:

- **a.** 5% integral line reactors to provide harmonic filtration.
- **b.** LON card.
- **c.** 5–year extended warranty parts and labor.
- **d.** Factory start-up.
- **e.** Three (3) contactor bypass feature on equipment without N+1 redundancy or critical equipment per design.

9. An early break/base block type disconnect shall be provided between the motor and variable frequency drive.

10. Provide disconnect switch within line of sight to motor (less than 10 feet between motor and VFD)

23 05 16 Expansion Fittings and Loops for HVAC Piping:

1. The specification section shall be written such that seismic support and anchorage design of piping is explicitly the sole responsibility of the contractor and shall be designed by a structural engineer. Alternatively, provide ISAT approved system.

2. The specification section shall be written such that the mitigation of thermal expansion and contraction of piping systems design shall be explicitly the sole responsibility of the engineer of record.

3. The design team shall ensure, however, that performance requirements are defined in the drawings to cover the following information:

a. Seismic expansion joints: Define maximum travel of seismic movement in each direction, and appropriate location of anchorage to the two sides of the movement joint. Specify Metraflex as the preferred seismic expansion device, and Hyspan or Metraloop ball joints as approved equals.

b. Thermal expansion of piping within the building: Define the maximum and minimum operating temperatures for the fluid within the piping. Specify Metraloop as the preferred thermal expansion device, with alternate devices by Metraflex and Hyspan as secondary preferences.

c. Thermal expansion for all tunnel piping: Ensure that structural supports can accommodate the thrust forces on startup and are coordinated with structural conditions, especially on steam piping systems. Assume a 50°F installation environment for heating piping and a 110°F installation for cooling piping. Provide proof of this accommodation of resistive forces for Caltech review.

1) Flexible neoprene or other suitable pipe connectors shall be used for connections to pumps on vibration isolators, concrete housekeeping pads, or inertia bases.
2) Flexible wire-braided pipe connectors shall be used for branch connections to heat transfer equipment with rotating and vibrating components.
3) All flexible pipe connectors and expansion loops shall be noted explicitly on the as-built drawings and identified in the operations and maintenance manual as requiring visual inspection on a 6-month basis.

23 05 19 Meters and Gauges for HVAC Piping:

1. Unless otherwise noted, Caltech prefers to have NO fixed-place pressure gauges or thermometers on ductwork and piping. Instead, Caltech prefers the following ports to be provided for the purposes of temperature and pressure sensing:

HVAC METERS and GAUGES TABLE		
Measurement Type	**Required Installation**	**Required Locations**
Air Temperature	Provide a permanent duct test hole with screw tap cap and extended neck to clear insulation	Outside air, return air and supply discharge at air handlers larger than 2000 cfm downstream of humidifiers
Air Pressure	Provide a permanent duct test hole with screw tap cap and extended neck to clear insulation	Each duct's exit from the riser (i.e., at each floor). Adjacent to each system duct static pressure sensor that is monitored by the energy management system

HVAC METERS and GAUGES TABLE		
Measurement Type	**Required Installation**	**Required Locations**
Room Differential Pressure	Over door at vivarium rooms between holding and anteroom. Over door at vivarium rooms between ante room and hallway. Over door at special quick-response pressurized rooms as agreed with Caltech.	Visual ADI ball-in-the-wall gauge for local visual verification and a differential pressure transmitter capable of analog output signal for remote monitoring and alarming purposes
Water Temperature and Water Pressure	Provide Pete's plug	At supply and return connections for: Tunnel utilities. All closed loop utilities. All closed loop heat-exchangers. All heating and cooling coils. Building-side connections of the laboratory equipment heat-exchangers.
Water Pressure	Provide ¼–inch full port ball valve for isolation, then mount Pete's plug to act as a gauge port	Adjacent to HHW system static pressure sensor that is monitored by the energy management system. At point of CHW supply furthest from the utility connection. At each supply pipe's exit from a riser (i.e., at each floor). At utility tunnel connections for CHW supply and return. At inlet and discharge of pumping units.
Steam Pressure Gauges	Provide hard-piped steam gauge with pigtail and isolation valve	At the tunnel utility entry. On both sides of the pressure-reducing station. At the inlet to the main heat-exchangers. At discharge of clean steam generator.
Flow Meters / BTU Meters	All building steam and hydronic systems	At the tunnel utility entry. To prove flow on the laboratory-side of laboratory heat exchange equipment.

2. Flow meters shall be used for energy monitoring:

a. Insertion Flow Meter: Onicon F-3500 Insertion Electromagnetic Flow Meter. (CHW, HHW, and steam)

3. Controls contractor and piping contractor to coordinate locations of thermowells for pressure transmitter ports.

23 05 23 General-Duty Valves for HVAC Piping:

1. The following chart lists the Caltech pre-stocked valve manufacturers for shutoff valve applications. These manufacturers shall be specified as sole sources of shutoff valves for all new projects in order to limit the stock requirements on campus:

HVAC PIPING GENERAL DUTY VALVE TABLE[1]		
Shutoff Valve Type	**Manufacturer / Size Requirements**	**Comments**
Ball Valves	Up to 2 inches: Nibco, 2–piece lead-free ball valve, T-585-70-66-LF 2.5 inches, Nibco T-585-66-LF	Valves with extended lever handle to accommodate insulation and shall be threaded, 2–piece, full port with stainless steel trim. Install threaded brass unions on the branch side to accommodate de-coupling.
Butterfly Valves	2.5 inches to 5 inches: Nibco, LD-3122-3 6 inches and larger: gear driven, Nibco LD-3122-5	Lug style, ductile iron body, 200 psig rated, EPDM seat material, aluminum bronze disk, 316 stainless steel stem, copper alloy upper and lower stem and bushing, brass collar, and lever lock operating mechanism. Valves 6 inches and larger shall have gear operated mechanisms in lieu of lever handles.
Gate Valves	2 inches to 8 inches: Nibco F-617-0	For steam applications 150 psi pressure, 353 degrees F
NOTES:	Install isolation valves for all branch mains, risers, and branch lines. Install threaded unions downstream of all isolation valves to facilitate convenient removal of the heat transfer equipment and control valves. All isolation valves, control valves, and unions shall have threaded end or flanged end connections. Valves installed for future connections or system expansion shall not be relied upon as the sole means of isolation. A threaded cap, plug, or blind flange rated for the system design pressure and temperature shall be installed downstream of the valve and shall remain in place until the future connection is made.	
[1]Refer to Mechanical and Plumbing Valves and Requirements in Appendix XII for additional information.		

2. Dedicated shutoff valves shall be provided in the following locations:

a. At each piece of equipment to isolate for maintenance. Shutoff valves shall be placed upstream of a union to allow full removal of the equipment-side piping.

b. Union shall be placed on branch side piping to equipment.

c. At all riser exits/entrances for all piping systems (to facilitate floor/zonal shutdown).

d. At the piping entrance from the utility tunnel.

e. At the piping entry of each laboratory suite.

f. All branch mains, risers, and branch lines.

g. Fan coils, reheat coils, heat exchangers, etc.

3. Refer to the mechanical piping table provided as part of Appendix XII for additional HVAC piping valve requirements.

23 05 29 Hangers and Supports for HVAC Piping and Equipment:

1. The specification section shall be written such that hangers and supports of piping is explicitly the sole responsibility of the contractor in accordance with SMACNA, FM Global, and the California Mechanical Code.

2. All insulated piping shall use load-rated insulated pipe supports, including both horizontal and vertical installations. All insulated pipe support inserts shall be sized to match the external dimensions of the pipe and shall incorporate an external sheet metal rigid hanger shield with a minimum of 12–inch-long metal sleeve centered on the hanger to spread the support's point load without crushing the insulation. Preferred manufacturer: Pipe Shields Inc.

3. In new construction, use imbedded inserts for hangers for installation of horizontal piping. In existing buildings under retrofit or in situations where an insert has to be dislodged, drilled-in expansion bolt locations will only be approved by the structural engineer on a case-by-case basis after a ferroscan is provided. Powder-actuated inserts are not allowed.

4. All pipework shall be supported in accordance with FM Global and SMACNA Guidelines for Seismic Restraint of Mechanical Systems, and part of an approved seismic restraint system stamped by a California licensed structural engineer. Preferred Manufacturer: Tolco, Mason West, Grinnell, or ISAT.

5. Provide clevis hangers where single pipe is run individually or trapeze hangers wherever there is more than one pipe traveling along the same path.

6. See section on vibration and seismic controls for piping required to be vibration isolated.

7. All welding to structural steel shall be performed by a tradesman certified under AWS D1.1. Welder's certification shall be submitted to Caltech for review by Caltech inspector.

8. All locations of penetrations of concrete or steel structure, or attachments to such structures that have not been explicitly approved through general guidance notes, shall be submitted to the structural engineer for a case-by-case review.

9. Supports shall be provided within 12 inches of a union at all reheat coils (union closest to the coil).

23 05 48 Vibration and Seismic Controls for HVAC Ducts and Equipment:

1. All HVAC systems shall be designed to seismic design category E.

2. Provide seismic bracing per latest applicable codes, FM Global, and SMACNA guidelines for all piping systems and HVAC equipment suspended more than 12 inches from the structural support system above.

3. Acoustical engineer shall select engineered vibration mounts to dampen the dominant frequency for heavy or pulsating equipment and shall select springs or rubber-in-shear for attenuation in the higher frequencies for light equipment.

4. **Preference**: Roof-mounted exhaust fans shall use seismic rail spring isolator base furnished by fan manufacturer specifically selected for the particular application.

5. Powder-actuated inserts are not allowed to support any pipe work. With prior written approval from Caltech, it may be used for support sheet metal of no more than 50 lbs of pull.

23 05 53 Identification for HVAC Piping and Equipment:

1. Hydronic piping identification shall conform to ANSI A131.1-1981 (the scheme for identification of piping systems)
2. Piping identification shall be manufactured by "Brady" or "Seton", "Setmark" system as follows:
    a. Pipes ≤ 6" outside diameter: Pre-coiled type snap-around labels.
    b. Pipes > 6" outside diameter: Flat type snap-around labels with metal ties.
    c. Pipe labels with adhesive backs are not acceptable.
3. All piping exposed or concealed in shafts or above ceilings shall be identified with markers at a distance not to exceed 10 feet 0 inches O.C. and shall include arrows showing the direction of flow.
4. All valves shall be identified by a numbered brass tag with hole and brass chain on valve stem or handle. Tag shall be a minimum of 1.5 inches in diameter and numbers and letters shall be at least 0.25 inches high, stamped into the tag.
5. Refer to the mechanical piping table provided as part of Appendix XII for additional HVAC piping identification requirements.

23 05 93 Testing, Adjusting, and Balancing (TAB) for HVAC:

1. Testing, adjusting, and balancing (TAB) is a construction-time process by which the contractor fine-tunes and then proves that the contractually required flow rates are achieved at each individual device on the project.

2. For the TAB specification:

a. The contract documents should explicitly define the procedures for the testing, adjusting, and balancing of air handling, refrigeration, hot water, and chilled water piping systems and other equipment as the basis of final acceptance. This shall include design conditions, tolerances, and the data to be obtained and documented in the reports submitted for final acceptance.

b. The contract documents shall explicitly identify the limited number of Caltech-approved TAB agencies to perform the testing, adjusting, and balancing under direct contract to the general contractor (i.e., completely independent of the mechanical contractor). The TAB agencies shall specialize in the balancing and testing of heating, ventilating, and air conditioning and shall be accredited by the Associated Air Balance Council (AABC).

c. Test and balance shall be the final step of construction after all other work is completed. All equipment start-ups shall have been completed by the manufacturer's representatives and documented on the commissioning agent's "pre-functional test" forms. Work shall be coordinated with control subcontractor so that controls are set and adjusted for the balanced system and the balance is realized with controls in adjustment.

d. Prior to the start of TAB work, all filters shall be replaced and all pipework strainers shall be cleaned by the mechanical subcontractor.

e. The TAB contractor shall investigate and report upon the adequacy of dampers and provisions for instrumentation and control and shall balance air and hydronic systems to tolerances indicated in this section and on the drawings.

f. It shall be the responsibility of the mechanical subcontractor to re-sheave fans or trim pump impellers to achieve the flow rates within 5% (unless otherwise specified), efficiencies, or pressurization relationships indicated on the drawings. This will be considered part of the contract at no additional cost to Caltech.

g. The tests shall be conducted in the presence of the authorized agent of Caltech, using mutually approved techniques and approved instruments that are factory calibrated just prior to the test.

h. Charging of the expansion tank shall be the responsibility of the mechanical subcontractor.

i. Post TAB QA/QC spot checks shall be performed for critical areas including laboratories, cleanrooms, vivaria, and other pressure-sensitive spaces. The extent of the spot checks shall not exceed 50% of the TAB scope for critical areas.

j. Post TAB QA/QC spot checks shall be performed for non-critical areas including offices, corridors, and support spaces. The extent of the spot checks shall be 20% of the TAB scope for non-critical areas.

k.TAB tolerances indicated in this section are target values. Air quantities within +/– 3% of design values shall be acceptable, provided required system operation and pressure relationships are maintained. Caltech may require +/– 1% tolerance of designated critical spaces.

l. Caltech will randomly spot check approximately 10% of the TAB scope to verify TAB results. The TAB contractor and mechanical subcontractor shall cooperate with these verification activities and provide access to contractor provided equipment, systems, and TAB documentation as required. Bidders shall account for this requirement in their bid. Testing equipment and activities will not be provided or performed by Caltech.

3. Upon completion of air balance, the contractor shall submit a complete report including:

a. Quantity of air handled by each fan by pitot tube traverse.

b. Air quantities at each supply outlet.

c. Air quantities at each return/exhaust intake.

d. For pressure-sensitive rooms, pressurization summary on a room-by-room basis that shows total room supply, total return/exhaust, differential cfm, and differential pressure across a closed door.

e. Total cfm for clean supply filters and for filters obstructed to simulate fully loaded condition.

f. The temperature drop across the cooling coil with controls locked to call for full cooling. Readings shall include entering and leaving air temperatures, entering and leaving water temperatures, and face velocity and size of coil.

g. The temperature rise across the heating coil with controls locked to call for full heating. Readings shall include entering and leaving air temperatures, entering and leaving water temperatures, and face velocity and size of coil.

h. AHU pressure profile.

i. Air and water DP across heating and cooling coils.

4. If the season during which the TAB report is generated has unsuitable outdoor air conditions to allow the full capacity of the heat-transfer coils to be proven, Caltech may request at no cost to the project that the TAB contractor either provide temporary artificial cooling/heating sources to prove capacity or, at the Institute's discretion, require that the TAB contractor return at a Caltech prescribed time in the next peak season to re-measure performance.

Section 23 07 00 – HVAC Insulation

23 07 00 General:

1. For the purposes of this section, the following definitions will apply:

a. Exposed Outdoors: any portion that is not fully enclosed within a conditioned space or a shaft/riser.

b. Exposed Indoors: any portion of piping/ductwork that is not within a shaft. All mechanical room piping and piping/ductwork exposed to view in conditioned space is considered to be exposed indoors.

c. Concealed Indoors: any portion of piping/ductwork that is within a shaft, piping/ductwork above dropped ceilings with access panels, or within a non-accessible (i.e., gypsum board) wall or ceiling void without access panel.

23 07 13 Duct Insulation:

1. Refer to **Appendix XIII** for Duct Insulation Requirements Table.

2. Where insulation on ductwork is required, it shall be provided externally unless explicitly designated as lined ductwork for acoustical reasons.

3. No fiberglass lining is allowed. Where lining is required for acoustical reasons, Armstrong or Rubatex closed cell elastomeric insulation shall be used. Where more than 1 inch of this lining is used, the engineer shall research the current flame-spread and smoke-developed test ratings to ensure compliance with the mechanical code.

4. Refer to latest California Energy Code Title 24 for minimum insulation requirements.

5. Exterior ductwork requiring insulation shall be insulated with spray-applied polyurethane foam. Refer to **Appendix XIII** for requirements.

23 07 16 HVAC Equipment Insulation:

1. Provide HVAC equipment insulation per the table below or the current version of the CMC, whichever is more stringent.

HVAC EQUIPMENT INSULATION TABLE		
Chilled Water Pipeline Equipment (Valves, Flanges, etc.)	Polyisocyanurate Rigid Foam or Elastomeric Armaflex	ASJ + PVC
Steam-to-Water Heat Exchangers	Semi-Rigid Glass Fiber	Pre-Molded Cover or Canvas Wrap
Air Separator, Expansion Tank, Steam Traps	Semi-Rigid Glass Fiber or Elastomeric	Canvas Wrap
Heating Hot Water Pipeline Equipment (Valves, Flanges, etc.)	Semi-Rigid Glass Fiber or Fiberglass Bag	Canvas Wrap
Chilled Water Pumps	Elastomeric closed cell insulation	Pre-Molded Cover

23 07 19 HVAC Piping Insulation:

1. Refer to the mechanical piping table provided as part of **Appendix XII** for allowable HVAC piping insulation and jacket requirements.

2. HVAC piping includes associated hydronic/steam trim.

3. Where piping is concealed in walls or shafts and not subject to physical damage, external jacketing will not be required.

4. Piping installed inside the utility tunnels shall be covered with heavy-duty canvas and Arabol (12 ounce per sq. yd.).

a. At Caltech's option, Saran vapor retarder with self-sealing lap over polyisocyanurate insulation will be acceptable for chilled water pipes (inside the utility tunnels).

5. Provide an insert section of rigid urethane foam insulation, at least 12 inches long, and centered on the hanger, at all pipe hanger locations. Where insert ID is larger than the pipe OD, provide a seal between the insert and insulation. Install an 18-gauge galvanized steel metal saddle under the hard insert (applies to all insulated utilities regardless of insulation type).

6. At Caltech's option, tubular preformed elastomeric insulation covered with PVC jacketing where it is exposed will be acceptable (special cases).

9. Chilled and cold-water piping subject to surface condensation, including medium temperature chilled/cooling water piping serving radiant devices (active chilled beams, ceiling panels, etc.), shall only be insulated with closed cell insulation materials. No fiberglass insulation shall be allowed for the chilled water piping or pipes carrying fluids below ambient temperature. For outdoor applications, polyisocyanurate rigid foam insulation similar to Trymer 2000XP is acceptable.

10. All exposed insulated piping shall be covered with PVC jacketing for indoor applications. (i.e., exposed to view, indoors)

11. All piping components subject to surface condensation or heat loss shall be insulated with appropriate thickness insulation and fire-retardant jacket. Refer to latest California Energy Code Title 24 for minimum insulation requirements and Caltech's utility piping matrix. Select the more stringent of the two requirements.

12. The heating hot water hydronic trim set on final branch reheat coils only may be left without insulation to allow for easy access and visible inspection of the valve and trim connection.

13. The chilled water hydronic trim on all equipment provided with chilled water shall be insulated with closed cell insulation (e.g., circuit setter, temperature control valve, strainer, union, isolation valve, etc.).

23 07 20 HVAC Insulation Jackets:

1. Insulation jackets shall comply with the following:

INSULATION JACKET TYPE TABLE		
Jacket Type	**Jacket Materials**	**Jacket Material Criteria**
ASJ	ASTM C291, White kraft paper reinforced with glass fiber yarn and bonded to aluminized film	Vapor barrier surface: Moisture vapor transmission: ASTM E96 – 0.02 perm inches. Secure with self-sealing longitudinal laps and butt strips. Then secure with vapor barrier mastic.
PVC	ASTM C291, one-piece molded type fitting covers and sheet material, off-white color PVC jacketing	Min. Service Temperature: –40 degrees F Max. Service Temperature: 150 degrees F Moisture Vapor Transmission: ASTM E96 – 0.002 perm inches Max. Flame Spread: ASTM E84 – 25 Max Smoke Developed: ASTM E84 – 50 Min. Thickness: 30mil Connections: Brush on welded adhesive, tacks or pressure sensitive color matching vinyl tape
Aluminum	Covered with ASTM B209 aluminum jacketing, 0.016–inch-thick ASJ and internally bounded vapor barrier over the entire surface in contact with the insulation	Thickness: 0.016–inch for installation not subject to mechanical damage. 0.032–inch is required for installation in harsh environment and subject to mechanical damage. Finish: Embossed Joining: Longitudinal slip joints and 2–inch laps Fittings: 0.024–inch-thick die shaped fitting covers with factory attached protective liner Metal Jacket Bands: 3/8–inch wide, 0.015–inch-thick aluminum or 0.01–inch-thick stainless steel

INSULATION JACKET TYPE TABLE		
Jacket Type	**Jacket Materials**	**Jacket Material Criteria**
Foam / Insulation and Jacketing		See foam roofing specification Section 07 57 00 for granular coating

Section 23 20 00 — HVAC Piping and Pumps

23 21 13 Hydronic Piping:

1. Refer to the mechanical piping table provided as part of Appendix XII for mechanical and HVAC hydronic piping requirements.

2. All piping installed on the roof shall rest on an engineered pipe support sleeper system, similar to Dura-Blok, properly mounted to the roof. Wood sleepers are not allowed.

3. All piping shall be stockpiled on site, protecting the cleanliness of the interior of the pipe by sealing both ends of each pipe air and watertight. Material shall be stored on pallets and covered in plastic. The pipe section shall be cleaned on the interior when installed, and once in place, the pipe shall be capped whenever work is not immediately occurring at that opening.

4. All welding of piping shall be performed by a tradesman qualified per ASME B31.1 and/or ASME B31.9 as applicable; AWS D1.1. B31.1 is applicable to all steam and condensate related pipe work above 15 psig and B31.9 is applicable to all other building service pipe work. Surface rust on piping, including at welded joints, is not acceptable.

5. Prior to the insulation of any piece of piping, the following procedures shall be performed:

a. Steel piping systems shall be chemically passivated for a minimum of 48 hours per Appendix X. Coordinate directly with Caltech.

b. Pressure test chilled water and heating hot water piping either hydrostatically with water as the testing medium or pneumatically with either compressed air or nitrogen as the testing medium.

1) Chilled water and heating hot water pipes less than or equal to 2.5 inches in diameter shall be tested using either the hydrostatic or pneumatic method; pipes larger than 2.5 inches in diameter shall be tested using a combination of hydrostatic and pneumatic testing using 95% water by volume and 5% compressed air to minimize any potential risks posed by stored energy in compressed air.

2) System piping and components shall be tested with a pressure of not less than 1.5 times the operating pressure but not less than 100 psig. Test pressure shall be held for a minimum period of 24 hours. Test pressure shall not exceed maximum pressure for any pump, valve, or other component in the system under test.

3) After pressurizing system, add a tick mark on pressure gauges indicating starting pressure and time/date of the pressure test along with pictures.

4) Any observed leaks or drops in pressure shall result in a subsequent repair and re-test of the entire piping system.

5) Pressure test shall be observed by a Caltech Inspector and signed off in writing.

6. All unions shall be readily accessible and marked for easy identification. Unions on heating hot water supply and return shall not be covered with insulation.

7. All portions of hydronic piping systems are to be capable of being completely drained down with manual drain valves conveniently located with access to a drain and manual air vents at the highest point for each 100–foot length of horizontal run. Air vents and drains are required as follows:

PUMPS and PIPING AIR VENTS and DRAINS TABLE		
Equipment Type	**Required Locations**	**Comments**
Automatic Air Vents	Closed pressurized system (e.g. process cooling water, heating hot water, chilled water, top of risers, etc.)	Pipe to the nearest approved receptor drain with ¼–inch copper tubing
Manual Air Vents	High side of each heat-transfer device. Each high point in the piping system on the floor layout. Top of risers as shown on the mechanical drawings.	Provide threaded hose end connection. Provide ¼–inch ball valve
Manual Drain Valves	Bottoms of risers	Ball valve sized as required by application. Coordinate with plumbing for nearby approved receptor drain
Manual Drain Valves	Each side of each heat-transfer device. Each low point in the piping system on the floor layout. Each main shutoff	

23 21 16 Hydronic Specialties:

1. In lieu of pressure independent circuit balancing valves, Caltech projects require installation of manual circuit balancing valves.

2. Strainers up to 2.5 inches shall be threaded on both ends. Strainers 3 inches and larger shall be flanged. All materials shall be compatible with the adjacent piping system. When dissimilar materials are installed, decouple them using a full-size 6” long brass nipple. Y-pattern strainers are allowed for installation on piping up to and including 4 inches in diameter; basket strainers are required on piping 5 inches and larger. All strainers shall incorporate a 3/4–inch blowdown ball valve with hose bib connection and cap.

3. Air separators shall be in-line, rated for 150 psig in accordance with the ANSI/ASME code.

4. Relief valves shall be bronze body, Teflon seat, stainless steel stem and springs, automatic-direct pressure actuated with capacities rated and certified by ASME.

5. Expansion tanks shall be bladder type rated for 150 psig with tank drain, pressure measurement connection on inlet and air-charge fitting.

6. Automatic vents to be Hoffman No. 78 only and the relief shall be piped to drain (**¼**–inch copper piping) at a plumbing receptor.

7. Manual vents to be a minimum of 3–inch extension above pipe sized at ½–inch diameter or larger pipe with bronze ball valve at the top of chamber.

8. Pressure-reducing valve to be provided at ICW connection for makeup to heating hot water system.

9. Manual balancing valves shall be circuit setter or approved equal. No automatic flow control valves are allowed.

10. Hydronic trim for heating and cooling coils shall be field fabricated including but not limited to isolation valves, unions, air vent, drain, strainer, reducer, Pete's plug, and control valve. See requirements in Appendix XI and Appendix XII**.**

11. Cabinet type fan coil unit cooling coil's hydronic trim shall be placed inside unit cabinet's auxiliary vestibule. External trim is only allowed for the heating coil.

12. Provide spring-loaded check valves on discharge of pumps.

23 21 23 Hydronic Pumps:

1. Heating Hot Water Pumps: The design, at a minimum, shall be comprised of two matched pumps arranged in parallel, each handling 100% of the flow ratio at the system design head. Pumps selected should have relatively flat characteristic curves and checked for single pump operation to be sure overload condition will not occur if one pump operates alone. Maximum pump speed shall be 1725 RPM except in special circumstances. Mechanical seals are preferred for most applications.

2. Where fan coil units or air handlers are mounted in such a way that a gravity-fed condensate drainpipe is not readily available, provide cold condensate drain pump with automatic float connection interlocked to shut down the fan and close the CHW control valve in the event that the pump has stopped or there is an excessive overflow.

a. Cold condensate drain pumps shall be Little Giant pump unit with 1/3–gallon receiver and auxiliary contact relays for alarming purposes.

23 22 13 Steam and Condensate Piping:

1. Refer to **Appendix XII** for Outline Mechanical and HVAC Hydronic Piping Requirements.

2. Hydronic piping requirements in Section 23 21 13 shall apply to steam and condensate piping.

3. Gravity steam condensate branch piping shall be connected to steam condensate mains via 45–degree angle tee or elbow connections.

4. Minimum gravity steam condensate piping shall be 1 inch.

5. Terminate the steam relief vent pipe a minimum 7'–0" above finished roof and a minimum 10'–0" away from fresh air intakes or other openings into the building.

6. Steam relief vent pipe shall be sized to handle flow rate at full 55 PSIG pressure when steam traps and pressure relief valves fail.

7. Each clean steam supply pipe from any clean steam generator shall be provided with a dedicated isolation valve.

8. Steam system piping shall be pitched downward in the direction of flow at ¼ inch per 10 ft unless noted otherwise.

23 22 16 – Steam and Condensate Specialties:

1. Float and thermostatic traps shall be used at heat exchangers and sized for the maximum differential pressure between apparatus and return line.

2. Inverted bucket traps shall be used at drip legs at mains and upstream of any apparatus.

3. All steam traps shall be arranged to allow the removal of the assembly.

4. Size steam traps to handle a minimum of two times the maximum condensate load of the apparatus served inside buildings and three times the maximum condensate load inside utility tunnels, and for mains with unsupervised startup. Heat exchangers with (2) steam traps can be sized for 1.5 times the maximum condensate load for each steam trap.

5. Steam air vents shall be balanced pressure type with stainless steel bellows, valve, and seat.

6. Vacuum breakers shall be provided on all modulating or on/off heat exchangers and steam coils, and installed on the supply side between the control valve and the equipment. Stainless steel body and all stainless-steel working parts.

7. Provide dirt pocket at all drip lines and apparatus connections equal in pipe size to adjacent pipe, and a minimum of 3 diameters high, with blow down valve. See detail **Steam Dirt Leg Trap Assembly** for additional information.

23 22 23 Steam Condensate Pumps / Receivers:

1. Steam condensate return pumps shall be of the electric centrifugal duplex type with cast iron receiver. Switching to an alternate service shall be accomplished by a mechanical alternator. Turbine type pumps shall not be used unless specifically approved by the Institute. Reference detail **Condensate Return Pump Connection** for additional information**.**

2. Condensate Receiver Drain Piping: Provide drain piping from condensate receivers to a floor drain with accessible isolation valve. Terminate with a minimum 3.5-inch air gap to permit condensate sample collection. Where required, drain piping shall be equipped with a water tempering device to limit temperature of discharged condensate in sewer system.

23 25 00 HVAC Water Treatment:

1. Chemical Pressure Pot Feeder:

a. All closed recirculation water systems, except where chilled water is supplied from the Central Plant, are to be equipped with a chemical pot feeder sized to accept water treatment chemicals in any common commercial form (solution, flake, balled, etc.), and arranged for shot feeding or for continuous feed.

b. Each installation is to be easily accessible for checking and maintenance and is to have a permanent label identifying the system it serves.

2. Expansion tanks shall be properly charged prior to fill of the system.

3. Coordinate with Caltech Central Plant for scheduling of connection to campus systems after the water treatment procedures below have been completed. It is the contractor's responsibility to ensure regular flow and chemical treatment in the building piping until the point at which Caltech allows the building to be connected to the campus systems.

4. Pipe the pot feeder in an upflow arrangement (i.e. high-pressure side to be on the bottom)

5. Provide isolation valves and unions on both sides.

Section 23 30 00 – HVAC Air Distribution

23 31 00 HVAC Ducts and Casings:

1. Ductwork, Except for Corrosive Fumes:

a. Ductwork is to be designed for a galvanized steel low pressure or medium pressure system in accordance with latest applicable SMACNA standards.

b. Ducts carrying heated or cooled air shall be insulated. Where internal lining is required, only closed cell insulation material, similar to "Armacell" or "Rubatex," is acceptable. The use of internal fiberglass lining insulation (i.e., products similar to "Circa-Liner") is strictly prohibited. See also Duct Insulation Table in Appendix XIII**.**

c. Exhaust ductwork shall be designed and operated to assure that static pressure within ducting remains negative to surrounding areas throughout the origin, run, and terminus of the ductwork.

d. The supply system should use radius elbows with a minimum r/d of 1.0. Where radius elbows are not feasible due to physical constraints, square elbows shall be provided with turning vanes. Ducts shall transform gradually, not exceeding 15 degrees divergence and 30 degrees convergence.

e. Provide balancing dampers or volume control devices for each individual air inlet and outlet. In instances where a single air inlet or outlet is served by an air terminal unit, balancing dampers may not be required.

f. The design of the ductwork systems must provide for noise control, accessibility for servicing and maintenance, and the ability to be balanced and adjusted for design operation.

g. The HVAC system shall be designed with an air-side economizer cycle that automatically allows the quantity of outside air supplied to the building to vary from 100% to the minimum amount required for ventilation. 100% air-side economizers shall include supply fans, return fans, and economizer damper sections. Refer to the latest applicable CEC and CMC requirements for the capacity thresholds.

h. All exposed ductwork supports installed on the roof deck shall rest on engineered support system sleepers similar to Dura-blok, properly masticked to the roof. Wood sleepers are not acceptable. Where exposed ductwork installed on the roof deck is elevated 24 inches above the finished roof surface, provide engineered seismic supports as required.

i. Variations in duct size and additional duct fittings shall be provided to clear obstructions and maintain clearances. Design engineer shall dictate within the specifications what methods of duct resizing are allowable, including maximum speed and aspect ratio. The specifications shall require that all deviations from indicated duct sizes be noted explicitly in the shop drawings for approval by the design engineer.

j. Slip and drive or equivalent flat seams for ducts exposed in the conditioned space or where necessary due to space limitations shall be provided. Longitudinal seams shall use Pittsburgh lock. Button punch snap lock systems

shall not be used. On ducts over 48 inches wide, provide standard reinforcing on inside of duct. Run-outs to grilles, registers, or diffusers on exposed ductwork shall be the same size as the flange outer perimeter on the grille, register, or diffuser. Painting inside of ducts behind grilles is not allowed.

k. All ductwork sizes indicated on drawings and other documents are clear net inside dimensions. Contractor shall be responsible for oversizing the ductwork dimensions necessary to compensate for the internal acoustical lining, if present. Caltech has the explicit preference that no exposed lining be used on any project, but, if necessary, only closed-cell/elastomeric lining is acceptable.

2. Ductwork for Corrosive Fumes, Grease Exhaust, or Steam Exhaust:

a. All exhaust ductwork associated with fume hoods and snorkel drops handling corrosive and harsh chemicals shall be stainless steel 316L and indicated on the plans and/or in the specifications. Round exhaust ducting shall be spiral stainless steel. Snorkel drops shall have volume dampers for modulation and blast gates for positive seal isolation. Where ductwork is used for exhausting steam and other condensable vapors and fumes, install heavy gauge 316L stainless ductwork with continuous welded seams. Spot welds are not acceptable.

b. When indicated on plans or specifications, exhaust air plenums on manifold exhaust air systems, exhaust canopy hoods, and other appurtenances associated with laboratory or special exhaust air systems shall be constructed of 18–gauge 316L stainless steel with continuous welded seams, unless noted otherwise. Flanged connections and/or spot-welded seams are prohibited.

c. Ductwork exposed to HF (hydrofluoric acid), Piranha, or other highly corrosive fumes shall be coated with a suitable product resistant to chemicals being exhausted, such as Halar by Solvay Solexi (ECTFE is marketed as Halar). As an alternative, FRP material may be considered acceptable with Caltech Planning, Design & Construction approval.

3. Where an external plenum exposed on the roof is to be used (for intake or exhaust), it shall be built from sheet metal and sealed per SMACNA. If the architect wishes to enclose that sheet-metal plenum within an architectural construction, the detailing of the sequence of installation shall be provided by the contractor to accommodate this construction feature. Under no circumstances shall an architecturally designed plenum be considered the air-tight plenum required by the mechanical ductwork system.

4. Access for Cleaning:

a. Cooling, heating, and ventilating main supply and return air ducts must be cleanable. Per the ductwork accessories guidelines, provide duct access doors at 50 feet on center, and in critical locations as needed.

b. Grease exhaust duct access doors to be installed per current California Mechanical Code requirements.

c. Provide sufficient access doors as needed. Major obstructions to access, such as banks of pipes, long buried runs, etc., should be avoided. The access door locations should be identified through labeling on the exterior visible surface of the ductwork or insulation.

5. At the time of rough installation and during storage on the construction site until final startup of the heating, cooling, and ventilating equipment, all duct and other related air distribution component openings shall be covered with tape, plastic, sheet metal, or other methods acceptable to the enforcing agency to reduce the amount of dust, water, and debris that may enter the system. Once installed, the duct section shall be wiped clean and a plastic taped cap installed on the open end of ductwork at any point when the duct is not being actively worked on. During construction activities generating dust within areas containing installed ductwork or air distribution components, the contractor shall implement dust control measures, including the use of negative air machines equipped with HEPA filtration where required to maintain construction area under negative pressures

and minimize migration of dust into duct systems. If at any time the Caltech representative sees that this procedure is not being used, the contractor shall provide, at no cost to Caltech, a high-pressure vacuum cleaning of the ductwork prior to the TAB contractor's work.

6. All ductwork potentially conveying flammable vapor that may exceed 25% of the lower flammability limit (LFL) shall be grounded to the building utilizing copper bonding. Bonding shall be coordinated with the electrical engineer and the building grounding system.

7. Provide high-pressure flexible duct connectors at all fan connections for units that are externally vibration isolated. Connector shall be neoprene coated glass-fiber fabric meeting the NFPA 90A requirements for flame spread and smoke development. Provide a sealed 8–inch length of sheet metal duct as the connection extension from the fan collar and attach the flexible connection to the extension piece. Connectors shall be UV resistant in outdoor applications.

8. Within MRI magnet rooms, it may be necessary to provide non-ferritic ductwork. The decision to do so will depend on whether the magnets are self-shielded. If non-ferritic ductwork is necessary, use ASTM B 209 Aluminum Sheet ANSI 1060 made of commercially pure aluminum no less than 0.025–inch thick. Use longitudinal seams.

9. 316L stainless steel ductwork shall be provided 5 feet upstream and 10 feet downstream of duct-mounted humidifier's dispersion tube.

10. Refer to Duct Insulation, Duct Pressure Testing, and Duct Jacketing excel matrix in Appendix XIII for duct pressure testing requirements. Duct pressure testing shall be in compliance with the latest editions of the California Mechanical Code and California Energy Code.

11. Outdoor horizontal ducts shall be pitched and provided with drainage outlets to prevent pooling water on top.

23 33 00 Air Duct Accessories:

AIR DUCT ACCESSORIES TABLE		
Equipment Type	**Required Locations**	**Comments**
Manual Dampers	Downstream of all automatic zone control dampers. Branch takeoff after leaving main. Duct leading to each grille or diffuser.	On ducts larger than 16" O.D. install opposed blade dampers. Opposed blade construction extended regulators to clear insulation damper regulators with indicators and quadrant locks. On ducts smaller than 16" O.D. provide butterfly dampers.
Combination Smoke / Fire Dampers (CSFD)	As required by code.	Provide resettable link, factory sleeve, and position indicator switches for pickup by fire alarm system. Design engineer to show the location of the actuator motors and the access doors required to reach them. Where ducts are so large that the smoke/fire damper is split into individual component pieces, the accessibility of all actuators must be shown on the design drawings. Provide types as approved and listed by the California State Fire Marshal and rated by U.L. 555 & U.L. 555S Horizontal fire dampers must be approved. External actuators are required. Coordinate duct access doors to ensure visual inspection of CSFD and access to actuator parts. CSFDs to be accessible, addressable, normally closed, and 110V motor.
Backdraft Dampers	All outside air inlets. Fan wall modules. Upstream of all exhaust fans. Branches of general exhaust systems where an odor-containing air stream may occur (i.e., toilets or kitchenettes). Manifolded exhaust fans.	Gravity balanced. For fan or ventilator systems, these may be provided by the manufacturer of the air-moving equipment.
Motorized Dampers	Multi-unit applications where air is supplied from two sources to a common duct system.	Backdraft dampers are not allowed in this application.
Flexible Duct Connections at Diffusers (for Fan Connections see Ductwork Guideline)	Final 5 feet of branch duct prior to the connection to supply and return diffusers. Also acceptable on general exhaust except for exposed applications and above hard-lid ceilings.	Flexible duct shall be rated for at least 2 inches in the positive pressure range and 1 inch in the negative pressure range. Product conveying and chemical exhaust ductwork is not allowed to have flexible ductwork.

AIR DUCT ACCESSORIES TABLE		
Equipment Type	**Required Locations**	**Comments**
Duct Access Doors	Upstream of control dampers Inlet and outlet of inline fans Upstream and downstream of CSFDs Upstream and downstream of filters At opposed blade dampers and backdraft dampers on exhaust fans Grease exhaust ducts per CMC Upstream and downstream of duct-mounted coils Every plenum At every 50 feet on center for cleaning access, S.A and R.A. mains	Provide insulated door if mounted on insulated ductwork. Provide hinged doors in all supply and return ductwork. Provide sandwich-type doors for all exhaust ductwork. Provide rated doors as necessary to meet code. Provide 24 x 60 doors at each plenum and 18 x 18 doors in all other locations.
Duct Test Holes	Outside air, return air, and supply discharge at air handlers downstream of humidifiers Each duct's exit from the riser (i.e., at each floor) Adjacent to each system duct static pressure sensor that is monitored by the energy management system	Provide a permanent duct test hole with screw tap cap and extended neck to clear insulation. Plastic plugs are not acceptable. These are provided for permanent test and measurement locations for Caltech's portable thermometers and pressure gauges.
Remote Manual Volume Damper (MVD) Operator (i.e., Young's Regulator Bowden Cable Type Operator)	For diffusers in inaccessible ceilings	These should be used as infrequently as possible. Explicit approval for the specification of these items is required from Caltech. Caltech will determine with the design team which diffusers may use them and where the screwdriver operators shall be placed. Spring wires shall be loosely cable-tied to the duct running between the damper and the diffuser it serves.

1. Combination Smoke/Fire Damper (CSFD) Requirements:

a. CSFDs to be accessible with damper position normally closed, and 110V motor.

b. CSFDs shall be provided with damper position indicator switch and connected to the building automation system (BAS) for remote monitoring of damper position(s).

c. Demonstrate the visual inspection of, resetting of, and actuator maintenance of CSFDs to Caltech prior to the official inspection by the local authority having jurisdiction. The actuators and resettable linkages must be shown to be accessible.

d. Smoke/fire dampers are to be controlled directly by the fire alarm system. The building automation system (BAS) shall not control the smoke/fire dampers. The mechanical contractor shall coordinate with the fire alarm contractor to install duct smoke detectors as required by Code, including those in the supply duct of air handlers sized over 2000 cfm.

e. All installed CSFD actuators shall be protected from the elements during construction. Smoke fire dampers that are wetted during construction shall be replaced at no cost to Caltech.

f. Coordinate with TAB contractor to flag volume damper locations.

g. Duct test holes used for balancing shall also be located in conjunction with the TAB contractor's requirements. Any test hole used for this purpose shall be noted on the TAB report and left with a permanent cap.

h. All CSFDs, FDs, and SDs shall be labeled appropriately per Caltech asset management naming convention.

2. Control damper general description:

a. Heavy-duty, low leak damper, galvanized construction for general non-corrosive applications or 316 stainless steel for corrosive applications designed with airfoil blades for higher velocity and pressure HVAC systems. Damper shall meet the leakage requirements of the International Energy Conservation Code by leaking less than 3 cfm/sq.ft. at 1" of static pressure and shall be AMCA licensed as a Class 1A damper.

b. Damper shall comply with AMCA 500-D – Laboratory Methods of Testing Dampers for Rating. Include leakage, pressure drop, and maximum pressure data.

c. Indicate materials, construction, dimensions, and installation details.

d. Include damper pressure drop data based on tests and procedures performed in accordance with AMCA 500-D.

e. Dampers shall be warranted against manufacturing defects for a period of 5 years.

f. Deliver materials to project site in manufacturer's original, unopened containers and packaging, with labels clearly indicating manufacturer, material, and location of installation.

g. Store materials in a dry area indoors and protected from damage and in accordance with manufacturer's instructions.

h. Handle and lift dampers by sleeve or frame only. Do not lift damper by blades, actuator, or drive shaft. Protect materials and finishes during handling and installation to prevent damage.

i. Performance Requirements:

1) Temperature Ratings: –72°F to 275°F.
2) Leakage: Class 1A, Maximum 5.5 cfm/ft² @ 10.0" wc.
3) Maximum Velocity: 4,000 fpm.
4) Differential Pressure Ratings: 10.0" wc

j. Frame: 5" x 1" x 16–gauge galvanized steel hat channel reinforced with corner braces for structural strength equal to 11–gauge channel frames. Low profile 3½–inch x 3/8" x 16–gauge galvanized steel channel top and bottom frame on dampers under 12" high. (16–gauge 316 stainless steel for corrosive applications.)

k. Blades: Galvanized steel airfoil shaped, double skin construction of 14–gauge equivalent thickness, 6" wide. Parallel blade or opposed blade action. (14–gauge 316 stainless steel for corrosive applications.)

l. Blade Seals: Polyethylene blade edge.

m. Axles: ½–inch plated steel hex, mechanically attached to the blade. Removable control shaft extends 6" beyond frame. (½–inch OD 316 stainless steel hex axle for corrosive applications.)

n. Bearings: Stainless steel or Oilite bronze sleeve. (Synthetic bearings are not acceptable.)

o. Linkage: Concealed in frame.

p. Maximum size: Single section – 60" w x 72" h (1524 x 1829) multiple section assembly – unlimited size.

q. Minimum size: Single blade – 8" w x 6" h (203 x 152).

r. Two blades, parallel or opposed action: 8" w x 10" h (203 x 254).

s. Finish: Mill galvanized [stainless steel].

t. Control Shaft: ½" x 3" drive axle.

u. Mounting: Vertical or horizontal as appropriate for each installation.

v. Provide optional damper features shown below as applicable to each installation.

1) Factory-installed, pneumatic and/or electric actuators.
2) Switch package to remotely indicate damper blade position.
3) Heavier frame construction with U-channel frame.
4) Damper sections with front, rear, or double flange frame with or without bolt holes.
5) All 316 stainless steel construction for laboratory and corrosive environments.
6) Manual locking quadrant.
7) Electric actuator, 120 v, 60 Hz, two position, fail [open] [close].
8) Electric actuator, 24V, 60 Hz, [two position] [modulating], fail [open] [close].
9) Electric actuator, 230V 50/60 Hz, two position, fail [open] [close].
10) Pneumatic actuator, 20 to 30 psi supply pressure, [two-position] [modulating], fail [open] [close].

23 34 00 HVAC Fans:

1. Pressure fans (i.e., for other than free or approximately free discharge) are to be backward inclined centrifugal fans with airfoil blades. Forward curved fans are allowed when part of factory manufactured central station air handling units, computer room units, or fan coil units if total static pressure does not exceed 2 inches. However, plenum fans and backward inclined air foil blade fans are preferable.

2. Fans are to be specified by cfm, mechanical efficiency static pressure, RPM, BHP, and wheel diameter, and also are to be selected for quietness of operation consistent with the design and the acoustical requirements of the space being served.

3. Fans are to be sized to operate at or near the peak of their efficiency curve.

4. Belt-driven fans are only acceptable when direct-drive fans are not able to satisfy the design criteria.

5. Direct drive fans are preferred. Belt-driven fans for handling chemical fume hood exhausts are to be supplied with a minimum of 2V belts each rated for at least 120% of the total load if belts are provided. A duct extension should be supplied at each fan discharge to exhaust the air upward at no less than 3,000 ft/min outlet velocity. Provide wind analysis and computational fluid dynamics (CFD) model to validate exhaust stack height, velocity, and cfm. Minimum discharge height shall be 15'–0" above the roof when stack height is calculated. If a high-induction fan is used or wind tunnel testing shows that a higher plume discharge height is required, then this shall be accommodated.

6. Chemical fume hood exhaust fans shall be spark-resistant construction, internally coated with Heresite (preferred) with rub ring and multi-piece motor cover.

7. All fans are to be constructed and rated in accordance with AMCA standards for both performance and sound, and the manufacturer must be a member of AMCA.

8. Direct drive fans with variable frequency drives or fans with electronically commutated motors (ECM) are preferred.

9. OSHA protective guards shall be provided around all motors, belts, and couplings as appropriate. Provide inlet and outlet protective screens.

10. Fans shall be coordinated with backdraft dampers (except at fume hoods) as required under the ductwork accessories guidelines.

11. Fans shall incorporate vibration isolation and inertia bases with spring isolators as required by the acoustical engineer. Electrical connections shall be flexible, and UV rated flexible duct connectors shall be provided per the ductwork guideline.

12. Fan bearings shall be rated AFBMA L–10 life of 200,000 hours, self-aligning, grease-lubricated bearings with extended lube lines.

13. Provide weatherproof cover for the motor, belts, and shaft coupling, as appropriate.

14. Smoke control fans shall meet the building codes requirements and shall be controlled by the fire alarm system. The EMS is not to be involved in fire and life safety control.

15. Roof up-blast fans may be used for toilet/kitchenette exhaust applications. Mushroom-type fans that discharge onto the roof are not acceptable.

16. Utility sets with appropriate stacks are recommended for lab exhaust applications. Discharge stack height shall be calculated by a qualified wind dispersion consultant using CFD and actual wind tunnel analysis; minimum discharge height shall be 15 feet when stack height is calculated.

17. Inline fans are not acceptable unless directed in writing by PD&C mechanical engineer.

23 36 00 Air Terminal Units:

1. The following chart shows the typical preferred use of terminal units (i.e., room level conditioning) on the Caltech campus:

AIR TERMINAL UNIT USE TABLE		
Equipment Type	**Required Locations**	**Comments**
Constant volume supply and exhaust boxes	Required for all laboratories and offices with a central AHU and exhaust fans. Consult with Caltech	Volumetric tracking between supply and exhaust to achieve the door leakage pressure differential direction desired.

AIR TERMINAL UNIT USE TABLE		
Equipment Type	**Required Locations**	**Comments**
Reheat coils provided by CAV box manufacturer	mechanical engineer for other areas.	Rooms also incorporate a differential pressure gauge mounted over the door; or a “ball in the wall” visual DP indicator. Electric actuators with digital temperature sensors.
Variable volume supply Plenum return with VAV box as necessary for pressurization control. Reheat coils by VAV box manufacturer	General use for non-laboratory office and classroom spaces	Gross floor-level volumetric tracking. This may require the installation of an extra flow monitoring station for the EMS. DDC thermostats shall be provided.
Variable volume supply and exhaust boxes Reheat coils by VAV box manufacturer	General use for laboratory benches and lab equipment areas except where fume hoods are located	Volumetric tracking between supply and exhaust to maintain a known differential. Electric actuators with digital temperature sensors.
AccuValve Laboratory Pressurization Control Valves Independent reheat coils mounted at supply discharge	Only used where variable volume fume hoods are located or by agreement with Caltech for rooms with special quick-response pressurization requirements.	Volumetric tracking between supply and exhaust to maintain a known differential. Usually, a 3–valve approach to pressurization control is used as follows: • Supply Valve • Fume Hood Exhaust Valve • General Exhaust Valve Electric actuators with digital temperature sensors unless torque requires a pneumatic actuator. On systems with high static pressure, high-torque actuators shall be required.
Fan Coil/Blower Coil Units	Used for spot supplemental cooling in labs, offices, and unoccupied areas (electrical and mechanical rooms).	Outside air ventilation shall be ducted from a fan system independent of the central air stations to these rooms. See also Caltech-special design guideline below for fan coil units. DDC TCV with DDC thermostat.

AIR TERMINAL UNIT USE TABLE		
Equipment Type	**Required Locations**	**Comments**
	Located within publicly accessible space or mechanical rooms.	
Computer room units	Used for server rooms and located within a closet adjacent to the room with doorway access from a hallway.	Outside air ventilation shall be ducted from a fan system independent of the central air stations to these rooms. Coordinate with responsible personnel to determine appropriate location for discharge and intake (down-flow vs. up-flow units). See also design guideline below for computer room units.
Humidifiers	Only for areas specifically required to have humidity control by the building program (i.e., vivaria, server rooms, labs, etc.)	Served from a DI water clean steam generator (either individual or central steam generator as applicable to the lab's needs). An electric steam generator or an unfired steam to clean steam generator may be acceptable depending on the program. Duct-mounted with room feedback humidistat and duct-saturation override. Temperature switch and duct DP switch. Unit must be compatible with DI water and of stainless-steel construction.

2. Air Terminal Units — CAV and VAV Boxes:

a. Provide pressure-independent devices.

b. Unit to be factory assembled including mounting of controllers provided by the controls subcontractor.

c. Flow sensor must provide a signal accuracy of ±5% and a minimum differential pressure signal of 0.03-inch wc at inlet velocity of 500 fpm.

d. Casing, damper, and inner working parts to be same steel type as the adjacent ductwork system (i.e., stainless steel if within stainless steel ductwork).

e. Terminals shall be single wall construction with a minimum of 1–inch insulation — no lining shall be exposed to the air stream; only fiber free lining is acceptable.

f. Minimum turndown shall be set by the design engineer to ensure stable throw at diffusers for mixing and to meet the requirements of the California Energy Code.

g. Size terminal unit for 1500 fpm velocity at inlet of the box at maximum cfm.

3. Air Terminal Units — Laboratory Pressurization Control Valves and System:

a. Laboratory Pressurization Control Valves or similar controllers shall only be used for those rooms containing fume hoods or for those rooms whose tight pressurization requirements have been pre-approved by Caltech Planning, Design & Construction. Where these standalone control systems are used, completely open protocol programming without proprietary locked software is required to be provided.

b. Manufacturer shall provide a complete system with supply and exhaust air valve, sash position sensors and monitors, local zone controller, and gateway interface to the EMS system.

c. Airflow accuracy of valves shall be ±5% of flow (not of full scale). Valves shall be pressure independent over a 0.6–inch to 3–inch wc range.

d. Fume hood exhaust side valves shall be stainless steel. Snorkel and biosafety cabinet valves shall be stainless steel. General exhaust valves shall be galvanized.

e. Minimum turndown shall be set by the design engineer to ensure stable throw at diffusers for mixing and to meet the requirements of the California Energy Code.

23 37 00 Air Outlets and Inlets:

1. Air outlets and inlets shall be selected for 10 dB lower than the stated NC level required by the acoustical engineer. This is to account for field-installation conditions, which may cause a higher noise generation than predicted by the laboratory testing that is the basis of the cataloged data.

2. Any single diffuser's pressure drop shall not exceed 0.07–inch wc.

3. Adjustable modular core diffusers with perforated faceplates are required for all OLAR-related facilities. Perforated faceplates may be omitted for certain offices and non-laboratory space applications.

4. Laminar or radial flow diffusers shall be used in the vicinity of fume hoods, laser curtains, labs with sensitive optical equipment, etc., and shall be located to avoid adverse interference with hood capture. Access to HEPA filters, when provided, shall be through face-access countersunk screws (i.e., room-side serviceable with gel seal).

5. All diffusers shall be constructed of aluminum with baked enamel finish to meet architectural requirements.

6. All supply air diffusers shall have square neck with acoustically lined plenums with maximum 5 ft. of flexible duct to prevent direct connection of duct to diffuser. If and when square necks are unavailable, size the diffuser sufficiently large to ensure minimum self-generated noise.

23 38 00 Ventilation Hoods:

1. Kitchen hoods shall be specified by the food service consultant. The mechanical engineer of record shall ensure that cfm and pressure developed is sufficient to accommodate full filter loading at the grease filters.

2. Fume hoods shall be specified by the laboratory consultant.

a. The mechanical engineer of record shall ensure that the cfm and pressure developed is sufficient to accommodate the full range of flows at the hood. Coordinate with fume hood selection if sash sensors are to be monitored by the air control valve system controllers.

b. Fume hood control valve systems shall be provided to have quick response to the position of the sash in order to maintain hood containment. In general, a three-valve approach to pressurization control is used as follows:

1) Supply valve

2) Fume hood exhaust valve
3) General exhaust valve

3. Steam canopy hoods at sterilizers and cage wash zones shall be designed by the mechanical engineer of record for condensate capture and drainage. Steam hood shall be made of 304 stainless steel.

Section 23 40 00 – HVAC Air Cleaning Devices

23 40 00 HVAC Air Filters and Cleaning Devices:

1. General requirements for all filters:

a. Clean filters shall be installed just prior to the start of the TAB balancing procedure.

b. Clean filters shall be installed at the time of handover to Caltech.

c. HEPA filters shall be labeled with their installation date clearly marked.

d. Blower coil and fan coil unit filters shall be side-loaded or bottom-loaded as needed to accommodate removal of the filter media.

e. Locate filter housing in a location that readily accommodates access to filter media without the need to remove or relocate other building system components.

2. Basic Particulate Air Filtration on Conventional Supply Systems Serving Occupied Spaces:

a. All air supplied to the spaces within the building should be filtered at central filter banks.

b. Prefilters shall be provided and be 4–inch–deep MERV8.

c. On systems serving occupied spaces, the final filter shall be 12– to 15–inch–deep pocket, and rated at MERV 13 or 14 as indicated in the OPR. Non-occupied spaces will not require final filters.

d. Size filter banks for filters in sizes 24 x 24 or 12 x 24 only, as these are the only sizes stocked at Caltech.

e. Inline fan filters, fan coil units, and computer room units with specialized filter sizes shall be approved by Caltech both during design and in the submittal phase. If a manufacturer cannot accommodate the Caltech stocked sizes, provide a duct-mounted independent filter bank instead of using the fan-mounted filters.

3. Special Filters on Exhaust Systems:

a. HEPA filters within laminar flow diffusers shall be provided with the laminar flow diffuser, but the HEPA filter shall not be installed until the time of the TAB balancing procedure.

b. Standalone bag-in/bag-out HEPA filters (for radioisotope hood exhaust or BSL exhaust) shall be standalone, self-supporting cabinet units with 100% positive shutoff (bubble-tight) dampers located upstream and downstream of each filter assembly. Filters shall be nuclear grade appropriate for biological containment. Cabinet shall have face-mounted differential pressure gauge with EMS connection for analog point. Radioisotope hoods shall incorporate carbon filters in addition to the HEPA filters.

4. Fan Powered HEPA Filter Modules:

a. Minimum 4–inch–deep filter media.

b. 99.99% filter media efficiency at 0.3 micron or larger particles, unless required otherwise to be ULPA as determined during the programming phase.

c. MERV8 efficiency ASHRAE-rated pleated pre-filter at the intake.

d. Room-side serviceable filter module with gel seal to allow replacement of the filter media without removal of the entire filter module.

e. Face velocity of the fan module not to exceed 85 fpm at highest fan speed setting.

f. Low watt energy efficient motor blower with backward curved impeller, single phase, permanent split capacitor type motor blower assembly with thermal overload protection. Units should be available in 115V (60 Hz), 208–230V (50/60 Hz) and 277V (60 Hz) as determined during the programming phase. Power consumption not to exceed 190 Watts at running condition.

g. Powder coated, aluminum, or stainless steel housing as determined during the programming phase.

h. Earthquake tabs.

i. Safety switch that disables the unit while servicing.

j. Solid state variable speed control with RFI suppression, allowing the airflow to be fine-tuned. Fan reset switches shall be installed remotely, outside of the clean space and in an accessible location.

k. UL listed (120V, 208–240V, 277V) with standard UL 900 class 1 filter, File number E152685 (UL507).

l. Duct Collar 10" (254 mm) and 12" (305 mm): Allows direct connection to the air conditioning supply (shipped loose).

1) Optional features to be provided as required:

a) Universal control card offering manual, Modbus, or analog options.
b) EC brushless motor with internal microprocessor.
c) Constant airflow over a wide range of external static pressures.
d) Forward-curved centrifugal-type fan.
e) Walkable plenum (excluding pre-filter), rated to 250 lbs.
f) Room-side replaceable or serviceable filter and motor/blower assembly.
g) Infrared Speed Control: Room-side airflow adjustment.
h) CE Marked: 230V units.
i) Ultra-low penetration air filter (ULPA): 99.9995% @ 0.12 micron (U15).
j) PTFE boron-free ULPA filter.
k) Fluorescent Light: Provides illumination with minimal airflow disruption.
l) Ion Bar: Neutralizes static charges below the filter.
m) Finish: Powder coat painted or stainless steel.
n) Room-side 3/8" Challenge Ports: Offers convenient aerosol challenge and HEPA filter testing.
o) 3/4" Knife Edge: Permits easy placement in gel track ceiling grid systems.

23 44 00 UVC Lights

1. **Provide UVC lights at the downstream section of all main cooling coils in air handlers to reduce the amount of organic bio-matter build-up in the drain pan and on the surface of fins.** FCUs and AHUs serving computer rooms, mechanical rooms, electrical rooms, and other utility rooms will not require UVC lights.

2. **Design Requirements**

a. Irradiation — Emitters and fixtures are to be installed in sufficient quantity and in such an arrangement as to provide an equal distribution of UVC energy on the coil and in the drain pan. To maintain energy efficiency, the UVC energy produced shall be of the lowest possible reflected and shadowed losses.

b. Intensity — Shall be measured by a solid-state photodiode UV sensor at the coil. Calibration wavelength is 254 nm. Accuracy is to be ±10% and be NIST traceable. Operating range shall be 35º F– 158º F read by a display module with a 3.5-digit LCD screen/panel. Irradiance range shall be 0–1999 (x10) µW/cm2 with a resolution of 9 µW/cm².

c. Installation — Emitters and fixtures shall be installed downstream of the cooling coil at right angles to the coil fins, such that UVC energy bathes all surfaces of the coil and drain pan. To prevent exposure to UVC rays, provide door interlock switches to disable the UVC lights when AHU door is in open position.

3. Equipment

a. Units shall be high output, HVAC-type, germicidal UVC light sources, factory assembled and tested. Components shall include a housing, reflector, high efficiency electronic power source, emitter sockets and emitter tube, all constructed to withstand HVAC environments.

b. DE, SEN, and SE unit housings shall be made of 304 stainless steel, with DE units having electrical connectors on both ends to simplify gang wiring and wiring to power. They shall include mounting holes to assist in securing the fixtures.

c. DE reflectors shall be constructed of high spectral finished aluminum alloy with a minimum 85% reflectance of 254 nm UVC energy.

d. High efficiency electronic power sources shall be 115 or 208/230 V, 50/60 Hz. They shall be UL listed to comply with UL Standard 1995 and capable of igniting each emitter at temperatures from 35º to 158º F in airflow velocities common to HVAC systems. They shall be equipped with RF and line noise suppression.

e. Emitter tubes shall be of the high output, hot cathode, T5 (15mm) diameter, and medium bi-pin type. They shall produce 95% of their energy at 254 nm and be capable of producing the specified output at airflow velocities common to HVAC systems and at temperatures of 35º - 158º F. UVC Emitters shall produce no ozone or other secondary contamination.

4. Installation of UVC Emitters

a. Coordinate with installation of HVAC equipment and install emitters as indicated after such equipment is properly installed.

b. Provide an interlock switch on all access doors to the UVC emitters to turn the lights off when access is opened.

c. If specified to include a UVR stationary radiometer, install the radiometer, adjust, and set in accordance with manufacturer recommendations.

d. Install provided Caution labels on all accesses to the emitters.

5. Acceptable Manufacturers

a. UVR Model DE[X], SLN[X], or SL[X] series as shown on drawings.

b. Substitutions: Ten (10) day prior approval is required and is to include documentation by a recognized industry independent testing lab on UVC emitter performances. Performance results must meet or exceed the performance for emitters in an HVAC environment as detailed above.

6. Quality Assurance

a. UL Compliance: Comply with UL Standard 1995 as applicable to usage of UVC emitters in HVAC equipment.

b. ISO Certification: Fixtures must be manufactured in an ISO 9001:2000 registered facility.

c. Comply with manufacturer's installation instructions on placement, wiring, and testing.

d. Qualifications: Each component and product is to be inbound and outbound tested before shipment in accordance with ISO 9001:2000 test procedures.

e. Output Verification: Independent testing shall indicate total output per one-inch arc length shall not be less than 9 uW/cm2, at one meter, in a 500-fpm airstream of 50º F.

7. Warranty: Fixture and emitter shall be 100% warranted to be free from defects for a period of one year. An additional prorated 4 years are warranted for the power supply.

Section 23 50 00 – Central Heating Equipment

23 57 00 Heat Exchangers for HVAC

1. The following heat exchangers are typically used on the Caltech campus:

Equipment Type	Required Locations	Comments
Shell and Tube Heat Exchangers Skid	Steam-to-heating hot water conversion	Provide field- or factory-mounted insulation for all components. HX steam working pressure: 12–15 psig Provide thermometer well, pressure gauge tapping, and valved drain at shell, at water inlet, and water outlet. Provide an ASME rated relief valve and an additional thermometer well for the temperature regulation sensor on the water outlet. Provide vacuum breaker connection on the shell. Provide evidence of hydrostatic test for 150 psig on water side. Show evidence of rating of steam side shell to 125 psig.
Plate and Frame Heat Exchangers	For building side control / laboratory process cooling water (PCW) systems	Provide field or factory mounted insulation for all components. Minimum 3" thick Provide stainless steel or titanium plates with studded port connections. Provide length to accommodate an additional 20% of plates. Provide insulation shroud. Provide evidence of hydrostatic test for 150 psig on both sides.

Equipment Type	Required Locations	Comments
Unfired Steam Generators	Production of clean steam	Provide field or factory mounted insulation for all components. Minimum 3" thick Provide as a complete package, including controller, relief valve, steam traps, feed water control valve, vacuum breaker, insulation, automatic blow down system including thermostatic mixing valve and pneumatic or electric temperature control valving. Insulation shall be a minimum of 3 inches thick. All components on the clean-steam side shall be 316 stainless steel. Control valve shall be sized for 50 psi inlet, clean steam pressure per building equipment requirements. 120V control connection shall be provided. Show evidence of rating of steam side shell to 125 psig.

2. All heat exchangers shall meet the ANSI/ASME Boiler and Pressure Vessel code requirements, with proof of certification via stamp.

3. See plumbing guidelines for water heaters.

Section 23 70 00 – Central HVAC Equipment

23 73 00 Indoor Central-Station Air-Handling Units – Custom-Packaged, Outdoor, Central-Station Air-Handling Units

1. Air handler units shall be double wall outdoor rated with thermal break construction and ETL listing. Units shall be specified to have sloping roofs and sealant equivalent to those provided on outdoor custom air handler stations because units are often stored outside during construction.

2. Configurations of the air handler, including drawings showing access doors, coil removal locations, and all electrical equipment access, shall be provided by the design engineer and enforced during the submittal process.

3. Air handlers shall be 2" double-wall construction with solid galvanized steel internal liners except downstream of the cooling coil where stainless steel internal liner is used. The fan plenum contains Mylar-wrapped fiberglass insulation placed behind perforated stainless steel liner. Balance of the cabinet insulation shall be closed-cell foam.

4. Access sections with checkered plate flooring, vision windows, and doors a minimum of 24–36 inches wide shall be provided on either side of each coil, upstream of the filter bank and fan inlet, and within the fan section itself.

5. Aluminum fin-copper tube cooling coils shall be installed with downstream UVC lights above stainless steel, floor-integrated, double-sloped drain pans meeting the ASHRAE Standard 62 requirements with P-trap arrangements sufficient to maintain a water seal under the full static pressure of the system. A face and bypass damper arrangement on a dual-piped cooling coil shall be considered so that one-half of the coil face can be engaged in dehumidification while the other half can provide either sensible only or no cooling, depending on the

psychometric state of the incoming air. Heating coils shall also be aluminum fin-copper tube and all coils (both heating and cooling) shall have fewer than 10 fins per inch and be no deeper than 8 rows. Cooling coils shall be sized for no more than 425 fpm and heating coils for no more than 700 fpm for maximum flow. For face-bypass arrangements, this should be carefully checked to account for the diversion of flow under extremes of mixing conditions. All coils shall have a minimum of 0.035–inch tube thickness and 0.01–inch fin thickness; air pressure drop for wet cooling coils shall not exceed 0.75-inch wc.

6. Provide seamless copper tubing with external headers; connections shall be red brass.

7. Fans shall be AMCA-rated and motors shall have a 1.15 service factor, utilize variable frequency drives for volumetric control, and be selected for their energy efficiency and low noise generation. On-board variable frequency drives shall incorporate a BACNET or LON interface card for communication with the EMS (see also Section 23 34 00 for additional fan requirements). Fans shall be direct drive, 12 blade fans. Fans shall be internally isolated on vibration isolators provided by the air handling manufacturer, but with minimum 1.5" static deflection defined by the project acoustical engineer. Vibration isolator bases shall be rated for seismic zone 4.

8. Filter sections shall consist of two independent stainless steel filter banks: one for a MERV8 pre-filter and one for a MERV 13 or 14 final filter per OPR. Provide individual gauges monitoring pressure differential across each filter for visual indication and a 4–20 mA output for EMS analog signal pickup.

9. Low-leakage dampers (less than 6cfm/ft2 at 5–inch wc) shall be provided in all shutoff and mixing applications. In units with economizers, dual outside air intake dampers shall be provided with one damper sized for minimum outside air volumes and the other for economizer mixing control. In-duct sensing of volumetric flow rate shall be provided on the minimum outside air volume, on the supply fan discharge, and on return and exhaust ducts. Utilize appropriate flow measuring device in each section. Damper construction shall include stainless steel bearings.

10. The air handlers shall include unit manufacturer leakage tests for all units to prove less than a 1% leakage rate at the maximum internal static pressure (including full filter loading). This test shall be performed in the field after the installation of controls devices, pressure test at 10–inch wc. Manufacturer shall furnish a written copy of the report to the design engineer.

11. Additionally, the cost of bid should include factory sound pressure tests on a minimum of three unique air handlers and the travel costs for up to 3 personnel identified by Caltech as required witnesses. Manufacturer shall furnish a written copy of the test results showing the test methods used. Proposed sound testing procedure shall be submitted with air handler submittal.

12. Provide airflow measuring device on all AHUs ≥ 5,000 cfm.

13. Provide a minimum 3–inch space between cooling coil and heating coil for installation of a temperature transmitter and/or relative humidity transmitter for BAS remote monitoring and control. Combination single piece heating/cooling coil slabs with a common header are not acceptable.

14. Motor removal rail and trolley system shall be required for all motor assemblies weighing more than 50 lbs. Rail and trolley system shall be factory designed and installed in the air handler fan cabinet by unit manufacturer. Rail and trolley system shall be positioned directly over the motor and perpendicular to the side of the air handler. Provide with additional extendable rail to hoist motor outside the air handler

Section 23 80 00 – Decentralized HVAC Equipment

23 81 23 Computer Room Air Conditioners

1. Double wall construction — up flow or downflow as selected in accordance with the server room's laboratory IT specialist.
2. When required, provide with adiabatic humidification.
3. Control panel shall be unit-mounted, but remote temperature and humidity sensors shall be provided for room mounting.
4. A moisture-detector leakage alarm shall be provided and hooked up to the EMS system monitoring points.
5. Filters shall be MERV13.
6. Drain pans shall be stainless steel, IAQ quality with dual slope.
7. Blowers may be forward curved or direct drive plenum style fans with EC motor.
8. Cold condensate drain pumps shall be specified where gravity-fed drainage cannot be absolutely assured, including any installation within a ceiling void that is shared with other disciplines.
9. Condensate pumps shall not be used to lift hot condensate.
10. Water supply shall be regular ICW water. Control system shall incorporate an automatic blowdown cycle and shall incorporate a thermostatically controlled mixing valve to mix down condensate and drainage to 140°F prior to discharge into an approved plumbing receptor.

23 82 16 Air Coils

1. **Duct Mounted Reheat**:
   - **a.** CAV and VAV box reheat coils shall be provided by the air terminal unit manufacturer.
   - **b.** Duct-mounted reheat coils shall be provided for the laboratory pressurization control system devices downstream of supply discharge and shall be controlled in conjunction with that system.
   - **c.** Seamless copper tubing with external headers shall be provided. Connections shall be red brass.
   - **d.** An adequate number of rows and fins per inch shall be provided to achieve the performance required.
   - **e.** Number of coil fins shall not exceed 10 FPI for all coil selections.
   - **f.** Minimum required fin thickness shall be 0.009 inches.
   - **g.** A minimum 2–row reheat coil and AHU/FCU heating coils shall be provided. Single row coils are not acceptable.
   - **h.** Evidence of factory testing of each unit to 150 psig working pressure shall be provided.
   - **i.** FCU and AHU coils shall have minimum 0.035–inch tube wall thickness and 0.01–inch fin thickness.

23 82 19 Fan Coil Units:

1. **Custom Cabinet Type Units**
   - **a.** Cabinet type construction lined with 1–inch closed cell lining on all panels; fabricated of continuous galvanized steel cabinet and finished with electrostatically applied baked-on paint.
   - **b.** Side and bottom access panels to remove and replace all serviceable parts.
   - **c.** Cooling coil section to be designed for 16°F delta T across the coil on the water side and with stainless steel casing.
     - **1)** Provide 6–8-row coils with no more than 10 fins per inch (FPI).
     - **2)** Coil shall be extended surface fin and staggered tube, constructed of ½–inch O.D. seamless copper tubing of 0.025–inch minimum wall thickness and aluminum fins.
     - **3)** All coils shall have manual air vents.
     - **4)** Optimize coil selection for minimum air pressure drop.
   - **d.** Maximum cooling coil face velocity not to exceed 450 FPM and 425 FPM on units handling 100% OSA.
   - **e.** Minimum 2–row heating coil section. Heating coil shall be downstream of the cooling coil.
   - **f.** DWDI forward curve centrifugal fan, dynamically balanced for low vibration, or direct driven BIAF fans with EC motors or BIAF fans with direct drive motors and variable frequency drives. When driven by a variable frequency drive, motor shall be provided with shaft grounding ring.
   - **g.** EC motors with integral inverter and 4–20 mA or 0–10 VDC control signal input.
   - **h.** Double sloped stainless steel drain pan insulated with closed cell insulation and sealed with mastic.
   - **i.** Primary and secondary condensate drain outlet.
   - **j.** 4–inch deep MERV8 pre-filter and 12–inch to 15–inch deep MERV 13 or 14 final filter per OPR on the cabinet type FCUs, readily accessible for replacement. (Final filter bank will not be required for fan coil units serving utility rooms, electrical room, mechanical rooms, etc.)
   - **k.** Cold condensate drain pumps shall be specified where gravity-fed drainage cannot be absolutely assured, including any installation within a ceiling void that is shared with other disciplines.
     - **1)** When condensate pumps are installed, flexible tubing shall be required on the suction and discharge sides of the pump, as needed.
   - **l.** Internal vestibule to accommodate the cooling coil's hydronic trim.
2. **Ductless/Ducted Type Units**
   - **a.** Multiaqua Chilled Water Fan Coils are manufactured with galvanized steel and high impact molded polymers.
   - **b.** Quality Assurance: ETL-certified in accordance with U.L. Standard 95, latest version (U.S.A.). Manufactured in a facility registered to ISO 9002, Manufacturing Quality Standard. Fully load tested at the factory. Damage resistant packaging.
   - **c.** General
     - **1)** Unit shall be a factory assembled and tested chilled and hot water fan coil.
     - **2)** Unit shall be assembled with high quality.
     - **3)** Contained within the unit shall be all factory wiring, piping, associated controls, and special accessories required prior to start-up.
     - **4)** Temperature control valve (TVC) shall be furnished and installed by mechanical contractor.
   - **d.** Unit Cabinet
     - **1)** Shall be composed of high impact polymers.
     - **2)** Shall be internally insulated to ensure quiet operation.
   - **e.** Fan Motors
     - **1)** Shall be available in 208/230-1-50/60 or 115/1/60.
     - **2)** Fan motors shall be three-speed, direct drive, and PSC type.
     - **3)** Totally enclosed.
     - **4)** Internal overload protected.

5) Unit shall contain a swing motor to modulate the discharge air.

f. Blower Wheels

1) Blower wheels are tangential and dynamically balanced.

g. Water Coil

1) Manufactured with water coils containing 3/8–inch copper tubing mechanically bonded to aluminum fins.

2) Coils shall be factory tested to 350 psig.

h. Drain Pan

1) Provide primary condensate drain pan for all fan coil units in accordance with the California Mechanical Code.

2) Units installed above ceilings or above critical lab equipment shall be provided with an auxiliary secondary drain pan or condensate overflow safety device.

i. Provide condensate drain pan overflow sensor and interlock switch for all fan coil units. Upon detection of high condensate level, the sensor shall de-energize the fan coil unit, force the chilled water control valve to fully closed position, and generate alarm at the Building Automation System (BAS).

ii. When called out on plans and/or specifications, galvanized steel secondary drain pans shall be provided. The discharge shall be piped to the nearest approved plumbing receptor via ½" copper tubing and terminated above the fixture in a clear and visible manner as required by code. Coordinate the point of termination with the Caltech project manager during the planning & design phase to identify a suitable and approved location for discharge of overflow condensate water. Condensate drain pan shall be installed in a manner to accommodate convenient removal incase the bottom access panels need to be opened for inspection and/or repairs.

3) All drain pans shall be molded with high impact polymers.

4) The exterior of all drain pans shall be insulated with closed cell to prevent condensation.

5) Pans shall contain a flexible drain tubing that is accessible from the back of the unit.

i. Filters

1) Unit shall contain 65% washable filters.

j. Controls

1) Fan coils are factory wired and tested.

2) Unit includes a terminal block that is capable of incorporating a 24 VAC, field supplied hard-wired thermostat.

23 84 00 Humidifiers

1. Humidifiers should utilize clean steam only.
2. Only steam injection humidifiers shall be provided for lab rooms and clean rooms.
3. Units shall be compatible with deionized water. All components exposed to either deionized water or clean steam shall be constructed of 316L stainless steel.
4. All tubes on the dispersion panel shall be 316 stainless steel.
5. Humidifier shall be provided with the appropriate steam control valve, steam strainer, steam trap, and steam isolation valve. Steam control valve shall be of stainless-steel construction with a minimum of 50:1 rangeability.
6. Coordinate with the ductwork guideline to ensure that stainless steel ductwork is provided within 5 feet upstream and 10 feet downstream of the humidifier.
7. Where in-room electric humidification using clean steam is to be used, coordinate these locations and equipment types with Caltech facilities personnel and the space planning intentions for the room and access clearances necessary for maintenance.
8. Where needed, provide a drain cooler to accommodate automatic self-flushing and temperatures greater than 140 º F.

SECTION 23 09 00 – BUILDING AUTOMATION SYSTEMS REQUIREMENTS

Section 23 09 00 – Instrumentation and Controls for HVAC Systems

1. **HVAC Instrumentation and Controls:**
   a. Control equipment for HVAC systems and components, including control components for terminal heating and cooling units not supplied with factory-wired controls.

See Appendix XXIV for specifications.

See Appendix XXV for alarms and point naming standards.

b. Definitions

BSO	Building Systems Operator
CC	Configurable Controller
CCS	Campus Control System
CCSI	Campus Control System Integrator (Controls Contractor)
DDC	Direct Digital Control
FAC or FOS	Facilities or Facilities Operations & Services Department
GUI	Graphical User Interface
INC	Interoperable Niagara 4 Controller
I/O	Input/output
JACE	Java Application Control Engine
LAN	Local Area Network
LonWorks, BACNET, and Modbus	Control network technology platforms for designing and implementing interoperable control devices and networks.
MS/TP	Master slave/token passing
NAC	Network Area Controller
NICS	Niagara 4 Compatibility Statement
OOT	Object Oriented Technology
PC	Personal computer
PICS	Product Interoperability Compliance Statement
PID	Proportional plus integral plus derivative
POT	Portable Operator's Terminal
RTD	Resistance temperature detector
SOO	Sequence of Operations
SUPO	Senior Utility Plant Operator
WAN	Wide Area Network
WBI	Web Browser Interface

c. System Performance:

1) Existing Niagara 4 supervisor provides all graphical user interface, trending, scheduling, and alarm functions for buildings on campus. The Building Automation System will interface with the campus Niagara N4 server, and the contractor will be responsible for all programming required to provide system graphics, alarming, trending, and reporting as required for the project. Specific requirements to be outlined by consultant for each project. Contractor is required to coordinate with campus Facilities a minimum of two weeks prior to start of implementation of project on N4 server.

2) Building Automation System shall comply with the following minimum performance requirements:

- **i. Graphic Display**: Display graphic with a minimum of 20 dynamic points with current data within 4 seconds.
- **ii. Graphic Refresh:** Update graphic with minimum 20 dynamic points with current data within 4 seconds.
- **iii. Object Command:** Reaction time of less than two seconds between operator command of a binary object and device reaction.
- **iv. Object Scan:** Transmit change of state and change of analog values to control units or workstation within 4 seconds.
- **v. Alarm Response Time:** Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.
- **vi. Program Execution Frequency:** Run capability of applications as often as five seconds but selected consistent with mechanical process under control.
- **vii. Performance:** Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at least once per second.
- **viii. Reporting Accuracy and Stability of Control:** Report values and maintain measured variables within tolerances as follows:
  - a. **Water Temperature:** Plus or minus 1°F.
  - **b. Water Flow:** Plus or minus 5% of full scale.
  - **c. Water Pressure:** Plus or minus 2% of full scale.
  - **d. Space Comfort Temperature:** Plus or minus 2°F of full scale, unless indicated otherwise in project specific design requirements.
  - **e. Lab Equipment Temperature:** Plus or minus 0.5°F of full scale, unless indicated otherwise in project specific design requirements.
  - **f. Ducted Air Temperature:** Plus or minus 1°F.
  - **g. Outside Air Temperature:** Plus or minus 1°F.
  - **h. Dew Point Temperature:** Plus or minus 1°F.
  - **i. Terminal Unit Velocity Sensor:** High turn down ratio approximately 1:10
  - **j. Relative Humidity:** Plus or minus 2 to 3%.
  - **k. Airflow (Pressurized Spaces):** Plus or minus 3% of full scale.
  - **l. Airflow (Measuring Stations):** Plus or minus 5% of full scale.
  - **m. Airflow (Terminal):** Plus or minus 5% of full scale.
  - **n. Air Pressure (Space):** Plus or minus 0.01–inch wc
  - **o. Air Pressure (Ducts):** Plus or minus 0.1–inch wc
  - **p. Carbon Monoxide:** Plus or minus 5% of reading.
  - **q. Carbon Dioxide:** Plus or minus 50 ppm with a 10–year calibration-free feature.
  - **r. Electrical CT Relay:** Plus or minus 5% of reading.
  - **s. Level Sensor:** Ultrasonic plus or minus 5% of full scale.
  - t. **Occupancy Sensor:** Dual mode/dual technology ceiling motion/IR.

3) Key HVAC energy conservation features:

- **i.** Operable window switches and interlocks to respective HVAC systems plus signage.
- **ii.** Dual max sequence of operation and air handling unit deck temperature reset, and duct static pressure reset.
- **iii.** Airside economizers based on dry bulb control meeting California's Title 24 requirements for related climate zone. Economizer dampers shall ensure minimum damper positions needed to provide require airflow per California's Title 24.

iv. Variable air volume chemical fume hoods with automatic sash closers versus constant air volume. Use pressure independent terminal air units/valves with face velocity reset and adjustable air change rate based on mode of occupancy.
v. Occupancy sensors and implementation of occupied/unoccupied modes of operation. Occupancy sensors shall utilize passive dual technology with infrared and motion detection with time delay, daylight sensor lockout, sensitivity control, 180–degree field of view with vertical sensing adjustment for flush mounting and external dry contact relay SPDT for lighting and HVAC equipment interlock. Occupancy based VAV setback shall utilize occupancy sensors hardwired to the DDC via an auxiliary relay output on the occ sensor itself. (Hard wiring is required versus single point integration to the lighting control panel.)
vi. Direct-drive fans with VFDs and communication card to match existing unit and building protocol.
vii. Steam, heating hot water, and chilled temperature control valve leak detection through building automation (pre-programmed Niagara N4 analytics feature).
viii. Prevention of simultaneous cooling and heating during temperature-only control mode.
ix. Outside air temperature and humidity sensors.
x. Adjustable room temperature sensors with display panel indicating actual room temperature and desired set-point.
xi. Commissioning.
xii. Trim and Response where there is feedback from all related zone equipment.
xiii. Temperature sensors downstream of cooling and heating coils.
xiv. UVC downstream of cooling coils on AHUs.
xv. Chemical fume hood exhaust fans with redundant fans with motorized isolation dampers for fans serving three (3) or more chemical fume hoods.
xvi. AHU deck discharge air temperature and static pressure reset.
xvii. Air-side economizers with supply fan, return/relief fan, and damper sections.
xviii. Heat exchangers with variable speed duplex or redundant pumps.
xix. Variable frequency drives for fan and pump operation.
xx. VAV box with terminal reheat and “dual max” sequence of operation.
xxi. 2–pipe FCU serving multiple rooms with terminal reheats and VFD or EC motor for fan speed control.
xxii. 4–pipe FCU serving individual zone utilizing VFD or EC motor for fan speed control.
xxiii. Laboratory fume hood exhaust valves with companion general exhaust and makeup air valves with reheat coil (AccuValve + Tek-Aire).
xxiv. Install a 2% accuracy temperature transmitter between the cooling coil and heating coil inside all AHUs and FCUs.

d. Sequence of Operation:
   1. The detailed sequence of operation for each controlled system shall be documented on the construction drawings and must be approved by Caltech prior to implementation.
   2. ASHRAE guideline 36 may be used as reference for development of the outline SOO. Specific SOOs shall be developed during the design phase and reviewed by Caltech’s Cx agent. All systems covered by ASHRAE guideline 36 shall use high-performance sequences of operation for HVAC systems as defined in the most current version of ASHRAE guideline 36 at the time of DDC implementation.

e. Submittals:
   1. Product Data: Include manufacturer’s technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
      i. DDC System Hardware: Bill of materials of equipment should indicate quantity, manufacturer, and model number. Include technical data for operator workstation equipment, interface equipment, control units, transducers/transmitters, sensors, actuators, valves, relays/switches, control panels, and operator interface equipment.
      ii. Control System Software: Software shall be stand-alone. See Components, Software section 2.c below. Custom control modules are not allowed.
      iii. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

iv. Schedule of dampers including size, leakage, flow characteristics, and required actuation force.

v. Schedule of control valves including flow characteristic, actuation characteristic, construction material, flow rate, size, position of failure, and required actuation force.

vi. Schedule of all flow meters (hydronic and air side), device tag, process system, process fluid, line/duct size, design process conditions, meter type, meter size, selected meter process information, communications protocol, manufacturer, and part number including all standard and optional features.

vii. Location of temperature sensors, pressure transmitters, control panels, and all other field devices

2. Shop Drawings: Detail equipment assemblies and indicate dimensions, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   i. Bill of materials of equipment indicating quantity, manufacturer, and model number.
   ii. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
   iii. Wiring Diagrams: Power, signal, and control wiring and must show point to point from all devices.
   iv. Details of control panel faces, including controls, instruments, and labeling.
   v. Written description of sequence of operation and detailed I/O points list schedule.
   vi. I/O points list schedule
   vii. Riser diagram
   viii. Controller wiring diagram
   ix. Equipment control layout
   x. As-built of communications trunk with floor plans
   xi. Check-out sheet per controller with initial values and approvals
   xii. Floor plan with field devices
   xiii. Submit shop drawings in DWG and PDF formats
   xiv. DDC System Hardware:
      a. Overall system/network architecture drawings: Submit block diagram(s) showing relationship of each controller, control panel, and other network devices relative to each other. Label room location of each controller/network device. Number and indicate model number of each device. Indicate network and communication protocol types.
      b. Wiring diagrams for control units with termination numbers.
      c. Schematic diagrams and floor plans for field sensors and control hardware.
      d. Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between operator workstation and control unit locations.
      e. Place a laminated hard copy of the control drawings in the control cabinet in the field clearly identifying the project location and all pieces of equipment being controlled.
   xv. Control System Software: List of color graphics indicating monitored systems, data point addresses (connected and calculated), output schedule, and operator notations. Caltech will provide a sample of graphic standards, which the contractors shall use as a reference.
   xvi. Controlled Systems:
      a. Schematic diagrams of each controlled system with control points labeled and control elements graphically shown, with wiring.
      b. Scaled drawings showing mounting, routing, and wiring of elements including bases and special construction.
      c. Written description of sequence of operation including schematic diagram.
      d. Point list for each system controller including, as a minimum, both inputs and outputs (I/O), point name, point description, point number, I/O type, scaled range, the controlled device associated with the I/O point, and the location of the I/O device. Configuration settings, alarm points, etc.
      e. Provide a backup copy of all the controls software on a flash drive to Caltech.
      f. Provide thermal zone maps
3. Informational Submittals.
   i. Data Communications Protocol Certificates: Certify that each proposed DDC system component complies with the most recent ASHRAE 135 and IEEE 802.3, and LonWorks, BACNET, or Modbus as applicable to the project. Consult with Caltech's DDC shop and obtain written permission on the BACNET versus LON selection prior to procurement and installation.

ii. **Qualification Data:** For installer and manufacturer.
iii. **Software Upgrade Kit:** For owner to use in modifying software to suit future systems revisions or monitoring and control revisions.
iv. Field quality-control test reports.
v. Submit in written form all newly created system access passwords and user IDs, if any.

4. Closeout Submittals.
   i. **Operation and Maintenance Data:** For HVAC instrumentation and control system to include operation and maintenance manuals (as-builts).
      a. System architecture diagram for components within the building annotated with specific location information.
      b. As-built drawing for each control panel
      c. As-built wiring design diagram for each control panel
      d. As-built system flow diagram for each system
      e. Sequence of operation for each system
      f. Binding map for the building
      g. Maintenance instructions and lists of spare parts for each type of control device.
      h. Interconnection wiring diagrams with identified and numbered system components and devices.
      i. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
      j. Calibration records and list of set points.
      k. Maintainable asset list submitted in accordance with the Caltech Asset and BMS Naming Standards. Provide and enter information for all maintainable assets along with application of labels.
      l. DDC program backup copy on flash drive – two copies on separate drives.
   ii. **Software and Firmware Operational Documentation:** Include the following:
      a. Software operating and upgrade manuals (digital copies).
      b. Device address list.
      c. Printout of software application and graphic screens.
      d. Software license required by and installed for DDC workstations and control systems. Hard copy of license data needs to be included in closeout package.
      e. All software licenses will be owned by Caltech – not the Vendor.
5. Maintenance Material Submittals:
   i. Furnish all materials described below that match products installed:
      a. **Maintenance Materials:** Any installation, calibration, maintenance tools, cables, or software needed to perform installation or maintenance of any device installed.
6. Quality Assurance:
   i. **Installer Qualifications:** Automatic control system manufacturer's authorized representative who is trained and approved for installation of system components required for this project.
   ii. Comply with ASHRAE 135 and IEEE 802.36 for DDC system components service.

2. Components:

a. The following requirements apply to product selection:

1) Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the work include, but are not limited to, manufacturers specified.

2) Manufacturers other than the ones mentioned below will require approval from the Caltech Facilities department. Upon project completion, submit operation and maintenance manuals, sourced from the following manufacturers:
   a. Honeywell International Inc.; Home & Building Control (residential T-stat)
   b. Johnson Controls, Inc.; Controls Group (pneumatic control only)
   c. KMC Controls (pneumatic controllers for legacy replacement only)
   d. Siemens – TCVs (actuators and field devices for legacy replacement only)
   e. Staefa Control System Inc.; Siemens Building Technologies, Inc. (as replacement for legacy controllers only)
   f. ABB (DDC controllers and variable frequency drives)
   g. AirSense (CO_2 sensors)

h. Belimo (TCVs and actuators)
i. Distech Controls (DDC controllers)
j. Dwyer (instrumentation)
k. Functional Devices Inc. (relays, power supplies, CT relays)
l. Kele (sensors and field devices)
m. Onicon (BTU Meters)
n. SkySpark (data analytics)
o. AccuValve (air flow controls valves and controllers, laboratory TAUs and controllers)
p. Tridium (Niagara framework software)
q. VYKON (JACE 9000 Series device)
r. WAGO (rail-mount terminal block system)

b. Software
1) Software licensing fees shall not impose any limitations to Caltech. Only a single purchase licensing fee will be acceptable. After the software license has been purchased, no annual renewal fees shall be required.
2) All software and database shall become the sole property of Caltech after initial purchase.
3) No license other than Tridium Niagara 4 is to be on the JACE network manager.
4) No proprietary control logic, custom modules, or graphics are to be used on the BMS that are license check dependent.
5) All points shall be programmed with a point name and detailed description. Refer to Caltech BMS Naming Standards Revision 2.0 for naming requirements. When additional controls points are necessary that are not covered under the point naming convention document, the controls contractor shall follow the guiding principles of the Caltech BMS naming convention to complete the point naming, and any new names generated during the project shall be shared with Caltech prior to programming for review.

c. Caltech Asset and BMS Point Naming Standards

d. Control System Quality Assurance:
1) Control system shall consist of new sensors, indicators, actuators, final control elements, interface equipment, other apparatus, and accessories required to control mechanical systems.
2) Control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, accessories, and software connected to distributed controllers operating in multiuser, multitasking environment on network and programmed to control mechanical systems. Existing operator workstations located in the Service Center and Central Utility Plant permit interface with the network via dynamic color graphics with each mechanical system, building floor plan, and control device depicted by point-and-click graphics.
3) DDC control points identified and tagged as per Caltech defined format (i.e., standard Tridium graphics). The most current version of licensed Tridium Niagara 4 shall be included.

e. Control Units: Modular, comprising processor board with programmable, nonvolatile, random-access memory; local operator access and display panel; integral interface equipment; and backup power source.
1) Units monitor or control each I/O point; process information; execute commands from other control units, devices, and operator stations; and download from or upload to operator workstation or diagnostic terminal unit.
2) Stand-alone mode control functions operate regardless of network status. Functions include the following:
i. Global communications capable of handling LonWorks, BACNET, and Modbus protocols. Specific communication protocol shall be reviewed and approved by Caltech's DDC Control Shop supervisor. Buildings utilizing existing BACNET or LON protocol shall continue using the same communication protocol. New base buildings shall be designed with BACNET communications protocol.
ii. Discrete/digital, analog, and pulse I/O.
iii. Monitoring, controlling, or addressing data points.
iv. Software applications, scheduling, and alarm processing.
v. Testing and developing control algorithms without disrupting field hardware and controlled environment.

f. Network topology with no critical logic control in the building network manager.

g. I/O Interface: Hardwired inputs and outputs tie into system through controllers. Protect points so that electrical shorting will cause no damage to controllers.

h. Provide controllers that can handle all types of points indicated below:
1) Binary Inputs: Allow monitoring of on-off signals without external power.

2) Analog Inputs: Allow monitoring of low-voltage (0 to 10 VDC), current (4 to 20 mA), or resistance signals.
3) Binary Outputs: Provide on-off or pulsed low-voltage signal, selectable for normally open or normally closed operation with three-position (on, off, auto) override switches and status lights.
4) Analog Outputs: Provide modulating signal, either low voltage (0 to 10 VDC) or current (4 to 20 mA) with status lights, two-position (auto-manual) switch, and manually adjustable potentiometer.
5) Tri-State Outputs / three-point, floating-type electronic actuators: Not acceptable on Caltech lab projects (acceptable for offices only).
6) Universal Inputs: Provide software-selectable binary or analog inputs.
7) Universal Outputs: Provide software-selectable binary or analog outputs.

i. **Power Supplies:** Transformers with Class 2 current-limiting type or overcurrent protection; limit connected loads to 80% of rated capacity. DC power supply shall match output current and voltage requirements and be full-wave rectifier type with the following:
1) Output ripple of 5.0 mV maximum peak to peak.
2) Combined 1% line and load regulation with 100-microsecond. response time for 50% load changes.
3) Built-in overvoltage and over-current protection and be able to withstand 150% overload for at least 3 seconds without failure.
4) Redundant power supplies shall be required for labs, OLAR-related facilities, and other critical applications.
5) No more than five (5) field devices, controllers, or actuators shall be served by a single transformer.
6) Generate an alarm for a failed transformer status.

j. **Power Line Filtering:** Internal or external transient voltage and surge suppression for workstations or controllers with the following
1) Minimum dielectric strength of 1000 V.
2) Maximum response time of 10 nanoseconds.
3) Minimum transverse-mode noise attenuation of 65 dB.
4) Minimum common-mode noise attenuation of 150 dB at 40 to 100 Hz.

k. **Unitary System Controllers.**
1) Unitized, capable of stand-alone operation with sufficient memory to support its operating system, database, and programming requirements, and with sufficient I/O capacity for the application.
i. Configuration: Local keypad and display; diagnostic LEDs for power, communication, and processor; wiring termination to terminal strip; memory with bios or bios-like; and 72–hour battery backup if no flash RAM.
ii. Operating System: Manage I/O communication to allow distributed controllers to share real and virtual object information and allow central monitoring and alarms. Perform scheduling with real-time clock. Perform automatic system diagnostics, monitor system, and report failures.
iii. ASHRAE 135 Compliance: Communicate using read (execute and initiate) and write (execute and initiate) property services defined in ASHRAE 135 and IEEE 802.3. Reside on network using MS/TP datalink/physical layer protocol and have service communication port for connection to diagnostic terminal unit.
iv. LonWorks /Lonworks Compliance Protocol: Communicate using EIA/CEA 709.1 datalink/physical layer protocol using LonTalk or BACNET protocol. (Confirm the proper protocol with the Caltech controls specialists prior to procurement of controllers and other devices.) It is the responsibility of the DDC contractor to ensure that the proper network variable inputs and outputs (NVI and NVO) are provided in each IDC, as required by the point charts located in the Points List section. Selection of the specific communications protocol for each project shall be discussed with the controls group and approved by the Caltech controls shop supervisor prior to design and engineering phase.

l. **Enclosures Plus Contents**
1) **Enclosure located indoors and dry locations where there is no possibility of water exposure**: Dustproof rated for operation at 32 to 120°F. (NEMA 12)
2) **Enclosure located outdoors and in mechanical rooms:** Waterproof rated for operation at 20 to 150°F. (NEMA 3R)
3) OLAR, OLAR-related, and critical facilities controllers are to have an uninterruptible power supply (UPS) (APC SUA500PDR-S or better) providing filtered backup power. Line voltage components and UPS unit shall be located outside the control panel NEMA 3R enclosure.
4) Provide 240W, 120VAC to 24VAC transformers with a reset button for controller. For non-critical systems, one transformer may to be used per a maximum of 3 controllers. For critical systems (air handling units, lab exhaust fans,

building heating hot water, building chilled water, any central OLAR-related systems, etc.), provide dedicated transformers per controller.

5) Locate the transformer and any other line voltage components in a dedicated enclosure separately and outside the DDC enclosure. Where multiple controllers are served by a single transformer, provide a separate disconnect (or fuse) for each controller.
6) Control panel's power supply is to have an RFI filter 24Vin–24Vout (e.g., TE Connectivity 2VB1 2amp.) in order to minimize radio frequency interference. (Line voltage components and UPS unit shall be located outside the control panel enclosure)
7) A 120V duplex outlet to power laptop or test accessories shall be located near, but not inside of control panel.
8) Control panel is to contain a box of spare fuses (5 ct.).
9) Control panel is to be provided with copy of the corresponding system control drawings and panel wiring diagrams inserted in a pouch or other containing method inside each non-terminal unit control panel.
10) Control panel is to have a LON or BACNET router as applicable.
11) Relays used in control panel are to have override switches.
12) Terminations are to be made using WAGO terminal block part # 2002-3201 or equal.
13) All enclosures are to have a secure padlock hook allowing for a padlock to be added.
14) Proper ventilation is to be taken into account when placing the UPS within a panel or enclosure.
15) For lab and other critical applications, provide a redundant power supply with all necessary relays to provide automatic switch-over when the primary transformer fails. Provide necessary alarming to notify the BSO of the transformer failure (latching alarm).

m. Network Managers (JACE): (VYKON JACE 9000 Series)

1) The JACE is to be used for network management only and shall not be used as a controller.
2) The JACE shall support up to 200 devices / 10,000 points and use only communication modules.
3) Quantity of JACE controllers is to be provided as required to meet the following requirements for each at time of commissioning:
   i. Each MS/TP trunk shall be limited to a maximum unit load of 25 with a max polling thread "busy time" no greater than 80% and an average polling cycle time no greater than 10 seconds.
   ii. Maximum nominal processor usage: 50%
   iii. Maximum nominal memory (RAM) used: 50%
   iv. Maximum file system usage: 80%
   v. Minimum heap. Free: 40%
   vi. Maximum RS-485 trunks used: 4
4) The use of remote IO modules is not allowed. No I/O communication shall be allowed over COM lines. All I/O interfacing shall be accomplished via hard wire from respective controllers.
5) The JACE and connected devices shall be set up/programmed for fail safe operation and should operate in safe manner upon the restart of the JACE or loss of the IP network.
6) Device points imported into the JACE may have history extensions added if needed, following the current Caltech guidelines. Do not add history extensions at the supervisor level.
7) Device points imported into the JACE may have alarm extensions added if needed, following the current Caltech guidelines. Do not add alarm extensions at the supervisor level.
8) BACNET/IP, Modbus/TCP, LON/IP, or any other IP devices/points that do not support Niagara 4 points shall be imported into the Secondary IP port of the JACE. Do not connect directly to Caltech's BMS VLAN.
9) JACE is to have 1GB DDR3 RAM.
10) The operating temperature range shall not excess: -4–140°F.
11) The JACE shall be powered by an uninterruptable power supply (UPS) (APC SUA500PDR-S).
12) UPS and line voltage transformer shall be installed in a separate enclosure.
13) UPS and line voltage transformer shall be connected to E-Power.
14) Prior to adding new controllers to an existing JACE, confirm the capacity of the JACE with the DDC shop. When needed, install a new JACE. Conversely, new JACE devices shall not be installed when the existing JACE has adequate capacity. Consult with Caltech's DDC shop prior to procurement and installation.
15) All graphics shall reside only on the supervisor server and not the JACE.
16) All graphics shall use native Tridium components.

n. Alarm Console:

1) Alarm console is to be based on Tridium's Niagara 4 Platform Alarm Console Monitor.
2) Alarms are to be concise and accurate and lead to the exact device and location that is in alarm.
3) Alarm descriptors are to be in clear, non-cryptic, plain English.
4) Proper instructions are to be tagged to the alarms where actions need to be taken or devices need to be reset.
5) Alarms are to be sent to the alarm console recipient that is monitored by the BSO or SUPO.
6) Filter alarms are to be sent to the proper email recipient located in the alarm class.
7) Alarms are to be displayed at the immediate time of the alarm state as defined by the SOO.
8) Include a hyperlink of all alarms in the GUI.
9) Refer to BMS Naming Standards Revision 2.0 for alarm class and descriptions. Alarms must conform to Caltech Niagara 4 Alarms Standards (standards to be furnished by Caltech DDC shop).

DDC Alarm Table

Niagara-Tridium Alarm Classification Table

Date: 08/19/2020
Rev. 00

Alarm Priority	Default Alarm Class /Type	Examples
1	Critical	life safety, loss of research, damage to equipment, damage to building, personnel injury, CFSD actuator failure
2	HVAC_Hi_Priority	Device fault and failure, AHU, FCU, EF, etc. affecting 10 or more people or research, motorized damper failure, control valve failure
2	HVAC_Hi_Priority	**OLAR-related project, out-of-range temperature, relative humidity, and pressurization**
3	HVAC_Alarms	General exhaust fan and restroom fan failure. Out of range temperature, relative humidity, and pressurization
4	EnergyAlert	Overrides, leaky valves
5	Maintenance	Filter alarm, bearing lube, belt replacement , etc.
6	JaceQC	CPU usage
255	Default class	Ping fail, advisory notification

o. Electronic Sensors and Misc. Components:

1) Description: All end devices shall be vibration and corrosion resistant for wall, immersion, or duct mounting as required.
2) Accuracy: Plus or minus 0.5°F at calibration point.
i. Wire: Twisted, shielded-pair cable.
ii. Insertion Elements in Ducts: Single point, 8 inches long; use where not affected by temperature stratification or where ducts are smaller than 9 sq.ft.
iii. Averaging Elements in Ducts: flexible; use where prone to temperature stratification or where ducts are greater than or equal to 9 sq.ft. Mount averaging sensor across duct area in a "Z" pattern using mounting clips specific for averaging temperature sensor probes. The length and type of the sensing element will be determined based on the specific application.
iv. Insertion Elements for Liquids: Brass or stainless-steel thermowell with minimum insertion length of 2½ inches or extend into middle 1/3 of the pipe.

v. Room Sensor Cover Construction: Manufacturer's standard locking covers.
vi. Set-Point Adjustment: Concealed.
vii. Set-Point Indication: Concealed.
viii. Thermometer: Concealed.
ix. Color: As per architectural requirement.
x. Orientation: Vertical.
xi. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
xii. Room Security Sensors: Stainless-steel cover plate with insulated back and security screws.

p. **RTD with Transmitter:**
1) **Accuracy:** Plus or minus 0.2% at calibration point.
2) **Wire:** Twisted, shielded-pair cable.
3) Insertion Elements in Ducts: Single point, 8 inches long; use where not affected by temperature stratification or where ducts are smaller than 9 sq.ft.
4) Averaging Elements in Ducts: 18 inches long, rigid; use where prone to temperature stratification or where ducts are larger than 9 sq.ft., length as required. Mount averaging sensor across duct area in a "Z" pattern using mounting clips specific for averaging temperature sensor probes.
5) **Insertion Elements for Liquids:** Brass or stainless steel thermowell with minimum insertion length of 2½ inches or extend into middle 1/3 of the pipe.
6) **Room Sensor Cover Construction:** Manufacturer's standard locking covers.
7) **Set-Point Adjustment:** Concealed.
8) **Set-Point Indication:** Concealed.
9) **Thermometer:** Concealed.
10) **Color:** As per architectural requirement.
11) **Orientation:** Vertical.
12) **Outside-Air Sensors:** Watertight inlet fitting, shielded from direct sunlight.
13) **Room Security Sensors:** Stainless-steel cover plate with insulated back and security screws.
14) **Output Signal:** Linear 4–20 mA

q. **Humidity Sensors: Application dependent**
1) **Accuracy:** 2% of full range with linear output.
2) **Room Sensor Range:** 0 to 100% relative humidity.
3) **Thermometer:** Concealed.
4) **Color:** As per architectural requirements.
5) **Orientation:** Vertical.
6) **Duct Sensor:** 0 to 100% relative humidity range with element guard and mounting plate.
7) **Outside-Air Sensor:** 0 to 100% relative humidity range with mounting enclosure, suitable for operation at outdoor temperatures of minus 22 to plus 185°F.
8) **Duct and Sensors:** With element guard and mounting plate, range of 0 to 100% relative humidity.
9) **Output signal:** Linear 4–20 mA or 0–10 VDC.

r. **Pressure Transmitters/Transducers:**
1) **Static-Pressure Transmitter:** Non-directional sensor with suitable range for expected input, and temperature compensated.
2) **Accuracy:** 2% of full scale with repeatability of 0.5%.
3) **Output:** Linear 4–20 mA or 0–10 VDC.
4) **Building Static-Pressure Range:** -0.5–inch to 0.5–inch wc.
5) **Duct Static-Pressure Range:** 0- to 5–inch wc or as required.
6) **Water Pressure Transducers:** Stainless-steel diaphragm construction, suitable for minimum 150-psig operating pressure service; linear output 4–20 mA or 0–10 VDC. Provide a 2–valve manifold to allow calibration.
7) **Water Differential-Pressure Transducers:** Stainless-steel diaphragm construction, suitable for service; minimum 150-psig operating pressure and tested to 300-psig; linear output 4–20 mA or 0–10 VDC. Provide a 5–valve manifold to allow calibration.
8) **Differential-Pressure Switch (Air or Water):** Snap acting, with pilot-duty rating and with suitable scale range and differential. Applications related to life and safety systems will require manual reset.

9) **Pressure Transmitters:** Direct acting for gas, liquid, or steam service; range suitable for system; linear output 4–20 mA or 0–10 VDC.

s. Room Sensor Cover Construction: Manufacturer's standard covers:

1) **Insulating Bases:** For sensors located on exterior walls and as needed.

t. Digital-to-Pneumatic Transducers: Convert plus or minus 24 VDC pulse-width-modulation outputs, or continuous proportional current or voltage to 0–20 psig.

u. Air Line Filter is to be placed on each main air line coming into panels containing the digital-to-pneumatic transducers (Kele UCP-722-PL):

1) **Particle Filters:** 97% filtration efficiency at rated airflow, quick-disconnect service devices.

v. Status Sensors:

1) **Current Switches:** Self-powered, solid-state with adjustable trip current, selected to match current and system output requirements.
2) **Electronic Valve/Damper Position Indicator:** Visual scale indicating percent of travel.
   i. Modulating valves/dampers: include 2–10 VDC, feedback signal.
   ii. Two-position valves: Actuators are to be provided with both "open" and "closed" indicating position switch dry contacts.
   iii. Two-position dampers: If damper shaft is keyed, not round or directly affixed to the actuator such that the shaft cannot slip and provide false position, "open" and "closed" indicating position switch dry contacts provided with actuator can be used. Otherwise, separate rotary switches are to be provided for indication of damper "open" and "closed" positions as required by design.
3) **Water-Flow Switches:** Adjustable setpoint, snap-acting type with pilot-duty rating, stainless-steel or bronze paddle, with appropriate range and differential adjustment, in NEMA 250, Type 1 enclosure.
4) **Manufacturers:**
   i. BEC Controls Corporation
   ii. ITM Instruments Inc.
   iii. Siemens
   iv. Kele

w. Gas Detection Equipment: (calibration free)

1) **Manufacturers:**
   i. B. W. Technologies
   ii. CEA Instruments, Inc.
   iii. EBTRON, Inc.
   iv. Gems Sensors Inc.
   v. Greystone Energy Systems Inc.
   vi. Honeywell International Inc.; Home & Building Control
   vii. INTEC Controls, Inc.
   viii. ITM Instruments Inc.
   ix. MSA Canada Inc.
   x. QEL/Quatrosense Environmental Limited
   xi. Sauter Controls Corporation
   xii. Sensidyne, Inc.
   xiii. Vaisala
   xiv. Siemens
   xv. Aircuity

x. Carbon Monoxide Detectors: Single or multi-channel, dual-level detectors using solid-state plug-in sensors with a 3–year minimum life; suitable over a temperature range of 32 to 104°F; with 2 factory-calibrated alarm levels at 50 and 100 ppm.

y. Carbon Dioxide Sensor and Transmitter: Single detectors using solid-state infrared sensors; suitable over a temperature range of 23 to 130°F and calibrated for 0 to 2%, with continuous or averaged reading, 4–20 mA output; for wall mounting.

z. Oxygen Depletion Sensor and Transmitter: Single detectors using solid-state zircon cell sensing; suitable over a temperature range of minus 32 to plus 110°F and calibrated for 0 to 25%, with continuous or averaged reading, 4–20 mA output; for wall mounting. Sensor shall be calibration-free for 10 years.

1) Where required, install multiple sensors at appropriate heights to ensure full coverage and occupant safety. The gas detection controller shall have the ability to archive its log data either locally (to itself), or remotely to a server or other gas detection controller on the network.

Oxygen depletion sensor(s) shall be installed in rooms housing cryogenic gases, nitrogen cylinders, LN2 dewars, liquid helium, liquid CO2, etc. Where displacement of breathable oxygen could pose a risk to occupant welfare and safety, sensor(s) shall be installed at breathing zone height as required by the manufacturer and applicable codes.

aa. Flow Measuring Stations:

1) Duct Airflow Station: Combination straightener and multiport, self-averaging pitot tube or thermal dispersion station.

2) Manufacturers:

i. Air Monitor Corporation

ii. Wetmaster Co., Ltd.

iii. Ebtron

iv. Dwyer

v. Ruskin

3) Casing: Galvanized steel frame.

4) Flow Straightener: Aluminum honeycomb, 3/4–inch parallel cell, 3 inches deep.

5) Sensing Manifold (Self-Averaging Pitot Tube): Copper manifold with bullet-nosed static pressure sensors positioned on equal area basis.

6) Sensing Manifold (Thermal Dispersion): Aluminum probe assembly with flanged connection and multiple hermetically sealed sensors in glass-filled polypropylene housing. Arrangement of sensors along probe assembly factory set to perform equal area traverse of duct cross section.

bb. Thermostats: (Distech Allure EC-Smart-Vue)

1) Electric, solid-state, microcomputer-based room thermostat with remote sensor. Provide features on an as-needed basis:

i. Temperature: plus or minus 0.9 degrees Celsius

ii. Humidity: plus or minus 2–3%

iii. Occupancy sensor

iv. CO2 sensor

v. Setpoint override

vi. remote sensor capability

cc. Thermostats shall comply with California's Title 24 requirement.

dd. Label sensors with standard tags or ID as defined per design guide standards.

ee. Label on or near room sensors with operating instructions to include actual temperature setpoint and override instructions.

ff. Humidistats

1) Humidistats shall be 2–3% accuracy as appropriate for the application and scope narrative.

2) Provide duct mounted relative humidity transmitters in addition to room combination sensors when design calls for tight relative humidity percentage tolerances.

3) Humidistats shall be of the "thin film capacitance with integrated circuit board" type and shall be capable of measuring 0–100% relative humidity in environments with -40˚F to +200˚F temperature range in a repeatable manner without experiencing failure due to saturation.

gg. Actuators (General)

1) Non-spring return motors for valves larger than NPS 2½: Size for running torque of 150–in-lbf and breakaway torque of 300-in-lbf
2) Spring return motors for valves larger than NPS 2½: Size for running and breakaway torque of 150–in-lbf.
3) Non-spring return motors for dampers larger than 25 sq.ft.: Size for running torque of 150–in-lbf and breakaway torque of 300–in-lbf.
4) Spring return motors for dampers larger than 25 sq.ft.: Size for running and breakaway torque of 150–in-lbf.
5) Actuators installed outdoors shall be NEMA 4X or IP66 rated or shall be provided with weatherproof NEMA 4X stainless steel enclosures that have removable covers that have clasps or machine screws (no sheet metal screws) and that do not require removing fasteners from the ductwork.

hh. Pneumatic Damper Actuators

1) Spring or non-spring return depending on application
2) Position indicator feature

ii. DDC Damper Actuators

1) Spring or non-spring return depending on application
2) Position Indicator feature

jj. Pneumatic Control Valve Actuators

1) Spring or non-spring return depending on application
2) Position indicator feature

kk. DDC Control Valve Actuators

1) Spring or non-spring return depending on application.
2) Critical applications require cooling coil control valve to fail in open position and heating coil control valve to fail in closed position with a mechanical spring return feature.
3) Spring-return actuators are required on all steam service control valves.
4) Position indicator feature
5) Control Valve Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
   i. **Valves:** Size for torque required for valve close-off at maximum pump differential pressure.
   ii. **Power Requirements (Two-Position Spring Return):** 24 VAC.
   iii. **Power Requirements (Modulating):** Maximum 10 VA at 24 VAC or 8 W at 24 VDC.
   iv. **Proportional Control Signal:** 2–10 VDC or 4–20 mA, and 2–10 VDC position feedback signal.
   v. **Run Time:** 12 seconds open, 60–90 seconds closed, or as required by application.

ll. Control Valves

1) Factory fabricated, of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated. Control valves shall have the following attributes:
   i. Stainless steel trim with threaded or flanged ends. Soldered ends are not acceptable.
   ii. Equal percentage characteristic or as appropriate for the heating hot water and chilled water applications. Steam control valves shall have “linear” characterization.
   iii. Pressure Rating: 150 psi
   iv. Chilled and heating hot water valves shall have minimum of 40 psig close-off pressure rating.
   v. Electronic control valve position indictor
   vi. Electronic control valve status
   vii. Control valves 5–inch and larger shall be butterfly type. Critical lab space temperature control valves shall be equal percentage globe valves, and non-critical office applications shall be characterized ball style for terminal unit reheat coils.
   viii. All control valves shall have stainless steel trim.

mm. Air Line Filter is to be placed on each main air line coming into panels containing the Electro-pneumatic transducers (Kele UCP-722-PL).

nn. Particulate Filters: 97% filtration efficiency at rated airflow, quick-disconnect service devices.

oo. Desiccant air dryers are not acceptable for HVAC control air.

pp. Variable Frequency Drives

1) Expose VFD points to the LON or BACNET card as needed (monitoring points only and not controlling points).

2) Hardwire fire life safety interlock to VFD. Fire alarm shutdown shall not be allowed to be done via DDC programming.

3) VFD shall have a 5–year extended warranty for parts and include labor with factory start-up and shall be programmed to include the following features:

i. Inject DC braking on multiple fan arrangements

ii. Self energize and recover after power disruption

iii. Adjust carrier frequency to minimize motor harmonic noise in the occupied space

iv. Three phase or E-Clipse bypass with service switch / electronic bypass with service switch. Provide bypass feature on equipment without N+1 redundancy.

v. Conventional 3–phase bypass

vi. 0–10 VDC for speed control

vii. Hardwire input signal for enable / disable

viii. Hardwire input signal for motor run status

qq. Control Wiring

1) Final connection points at devices and panels shall be made either at terminal blocks integral to device or at separate terminal blocks mounted inside of control panel enclosures. Use of wire nuts and crimped connections are not allowed for terminating control wiring unless approved by engineer.

2) Wires smaller than #18 AWG shall not be used, except for manufacturer supplied instrument specific wire, or where otherwise specified. Use 2–wire stranded twisted/shielded pair 24 VDC for analog and discrete input and 24 VAC/VDC output devices. For 3-lead RTD signal wiring, use #18 AWG stranded, tinned copper twisted/shielded 3-conductor.

3) Provide metal oxide varistors (MOVs) on 24 VAC/VDC discrete outputs connected to inductive loads to reduce noise levels (i.e., solenoid valves, motor contactors, relays, damper/valve electric actuators, etc.).

3. Execution and Commissioning

a. Installation: Line voltage wiring must be run within EMT conduit, unless indicated otherwise.

1) Install systems and materials in accordance with manufacturer's instructions, rough-in drawings, and equipment details. Install electrical components and use electrical products complying with requirements of applicable Division 26 sections of these specifications.

2) The term "control wiring" is defined as low voltage control wiring and is meant to include the wire, conduit, and miscellaneous materials required for mounting and connecting electric or electronic control devices.

3) All exposed low and line voltage wiring subject to mechanical damage shall be run in EMT conduit (e.g., control wiring in mechanical spaces, mechanical attics, mechanical catwalks, and interstitial spaces, etc.).

4) Line and low voltage wiring shall be run in separate conduits.

5) Except in mechanical spaces, concealed but accessible low voltage DDC wiring run in ceiling plenum space above occupied rooms shall not require conduits and may be run free-wire style. Provide J-hooks or rings when not run in conduits. When installed in active ceiling air plenums all such wiring shall be UL plenum rated cables as approved by code. Control wires above T-bar ceilings shall be supported by a cable management system of 8'–0" O.C. support points or 4'–0" O.C. maximum for J-hooks.

6) All low voltage DDC wires shall be clearly labeled to indicate the terminals they land to and devices they serve. Label both termination ends according to the field device it is connected to.

7) Install software in control units and operator workstation(s). Implement all features of programs to specified requirements and as appropriate to sequence of operation.

8) Connect and configure equipment and software to achieve sequence of operation specified.

9) Verify location of thermostats, humidistats, and other exposed control sensors with drawings and room details before installation.
10) Install averaging elements in ducts and plenums in crossing or zigzag pattern.
11) Install labels and nameplates to identify control components. Provide self-adhesive Brady type labels on each thermostat with operating instructions.
12) Control wires above hard-lid ceilings and inside walls shall be run in conduits to allow replacement or addition of wiring in the future.
13) Where penetrations of fire-rated assemblies are involved, seal penetrations with appropriate firestopping systems.
14) All devices/instruments and cable/wiring located inside animal facility or containment suite boundaries shall be installed according to project electrical requirements for these specialty space types.

b. Field Quality Control:

1) Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. **REPORT RESULTS IN WRITING.**
2) Perform the following field tests and inspections and prepare test reports:
   i. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
   ii. Test and adjust controls and safeties.
   iii. Test calibration of pneumatic and electronic controllers by disconnecting input sensors and simulating operation with compatible signal generator.
   iv. Test each and every I/O point through full operating range to verify safety and operating control set points are as maintained.
   v. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions as necessary.
   vi. Test all systems for compliance with sequence of operation.
   vii. Test software and hardware interlocks.

c. Pneumatic Verification:

1) Verify that instruments are installed before testing, calibration, and loop or leak checks.
2) Check instruments for proper location and accessibility.
3) Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
4) Check instrument tubing for proper fittings, slope, material, and support.
5) Check installation of air supply for each instrument.
6) Check flow instruments. Inspect tag number and line and bore size and verify that inlet side is identified and that meters are installed correctly.
7) Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.
8) Check temperature instruments and material and length of sensing elements.
9) Check control valves. Verify that they are in the correct direction.
10) Check air-operated dampers. Verify that pressure gauges are provided and that proper blade alignment, either parallel or opposed, has been provided.

d. DDC Verification.

1) Verify that DDC controller power supply is from emergency power supply, if applicable.
2) Verify that wires at control panels are tagged with their service designation and approved tagging system.
3) Verify that spare I/O capacity has been provided.
4) Verify that DDC controllers are protected from power supply surges.

e. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

f. Adjusting

1) Calibrating and Adjusting Instruments:
   i. Make a three-point calibration test for both linearity and accuracy for each analog instrument.
   ii. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
2) Control System Inputs and Outputs:
   i. Check analog inputs at 0, 50, and 100% of span.
   ii. Check analog outputs using milliamp meter at 0, 50, and 100% output.
   iii. Check digital inputs using jumper wire.
   iv. Check digital outputs using ohmmeter to test for contact making or breaking.
   v. Check resistance temperature inputs at 0, 50, and 100% of span using a precision-resistant source.
3) **Flow:**
   i. Set differential pressure flow transmitters for 0 and 100% values with 3–point calibration accomplished at 50, 90, and 100% of span.
   ii. Manually operate flow switches to verify that they make or break contact.
4) **Pressure:**
   i. Calibrate pressure transmitters at 0, 50, and 100% of span.
   ii. Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.
5) **Temperature:**
   i. Calibrate resistance temperature sensors and transmitters at 0, 50, and 100% of span using a precision-resistance source.
   ii. Calibrate temperature switches to make or break contacts.
6) Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100% open and closed.
7) Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100% closed.
8) Provide diagnostic and test instruments for calibration and adjustment of system.
9) Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating startup procedures.

g. Adjust initial temperature, pressure, flow, and humidity set points.

1) **Occupancy Adjustments:** When requested within 12 months of the date of substantial completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to three visits to project during other than normal occupancy hours for this purpose. The system must have the capability of having room numbers changed without damaging other points elsewhere in the Niagara 4 platform.

h. Demonstration.

1) Engage a factory-authorized service representative to train owner's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls.

i. Sequence of Operations

1) Unoccupied versus occupied mode of HVAC operation.
2) When practical, implement a variable air volume [VAV] mode of operation versus constant air volume [CAV] to maximize energy conservation (typical for labs and offices).
3) The type of chemical fume hood (i.e., VAV versus CAV) will need to be looked at in detail by the design team. For labs with large internal volumes and only one or two chemical fume hoods, a VAV style fume hood may be cost prohibitive. Consider constant air volume [CAV] HVAC system for said applications. The design team needs to analyze the minimum ventilation rate versus the additional project costs to determine the most appropriate system.
4) Variable air volume chemical fume hoods shall be equipped with automatic sash closers. When proximity sensor determines there are no occupants in front of chemical fume hood for longer than 10 minutes (adjustable), it will command the sash to go to closed position and enable automatic exhaust air flow rate turn-down. Automatic sash

closing system shall be capable of detecting objects protruding from inside the fume hood that may be in the path of sash travel, preventing the sash from being automatically closed.

5) Occupied mode of operation: HVAC system shall be designed and programmed to operate in VAV mode with Supply air and exhaust air flow rates as dictated by either cooling load demand, exhaust air flow rate, or ventilation flow rate, whichever dictates the highest flow rate. Operational hours are based on a certain schedule as defined by lab programmer or the PI.

6) Unoccupied mode of operation: HVAC system shall have the capability to be reset resulting in higher or lower room air temperature (adjustable) as determined by lab programmer or the PI. Non- operational hours are based on a certain schedule as defined by lab programmer or the PI.

7) Room temperature sensor shall be provided with an override button to allow room occupants to defeat the unoccupied mode of operation and restore the air flow rate and temperature back to normal.

8) When project or space does not have dual technology occupancy sensor(s) provided as part of the lighting system, install occupancy sensor(s), as needed, to enable an automatic override of the unoccupied setback mode (safety feature). Occupancy sensors provided as part of the lighting system shall be provided with auxiliary contacts and utilized to the extent possible. Occupancy sensors shall be capable of detecting occupants by means of infrared and motion (i.e., dual mode capable). Provide adequate number of occupancy sensors, as per manufacturer's recommendation, to provide proper coverage to the entire laboratory or office.

9) Air flow reduction during the unoccupied mode should have no impact on space temperature and/or relative humidity. HVAC system shall have the capability to maintain space temperature in labs and offices in either occupied mode or unoccupied mode of operation. This issue needs to be discussed during lab programming phase and confirmed by the design team.

10) Supply air and exhaust air in each lab shall be designed and arranged to allow independent operation of each lab. Provide supply and exhaust terminal air units as necessary to accommodate independent operation of each lab.

11) The only acceptable manufacturer of supply and exhaust air terminal air units and DDC controls package for use on VAV type chemical fume hoods is ACCUTROL. Under certain conditions, Distech controllers are also acceptable.

12) Laboratories: Reduce the minimum ventilation rate for supply and exhaust air flow rates during the unoccupied mode of operation to a 4.0 air changes per hour (ACPH) during the unoccupied mode of operation and 6.0 air changes per hour during the occupied mode of operation. Confirm the actual required ACPH with EH&S.

13) Offices: Reduce the minimum ventilation rate for supply and return air flow rates during the unoccupied mode of operation to values required by CMC during the unoccupied mode of operation.

14) Office spaces shall always be maintained under positive air pressure with respect to labs, under all modes of operation. Conversely, laboratories with chemical contents or chemical fume hoods shall remain under negative air pressure with respect to office spaces. A differential air pressure of 0.07" wc ±0.02" wc shall be maintained.

15) When chemical fume hoods operate in VAV mode, provide a general exhaust terminal air unit to compensate for the fume hood turndown. Both supply and exhaust systems need to be compatible with the operation of chemical fume hoods in VAV mode.

16) VAV mode: Provide VFD units for the exhaust fan(s) to facilitate maximum energy conservation. In addition to VFDs, exhaust fans will require a motorized bypass damper on the roof to ensure adequate discharge stack velocity when chemical fume hood / lab exhaust air flow rate is reduced. Seek recommendations of a specialized wind dispersion consultant for the minimum flow rate and discharge stack velocity to mitigate any re-entrainment issues.

17) Provide VFDs to accommodate the VAV mode of operation on fan coil unit applications.

18) Design-build team shall coordinate their work with the controls contractor and commissioning contractor at the earliest stage of design possible to ensure all critical components are accounted for and budgeted.

19) Provide CO2 sensors in high occupancy rooms to implement demand ventilation and take advantage of reducing OSA and dual max sequence of operation shall also be utilized to minimized HVAC related energy consumption. The sequence generally calls for continuous air handling unit deck temperature and deck pressure adjustments based on

constant polling of terminal air units and space temperatures. Refer to ASHRAE white paper articles for additional details.

20) VFD and DDC controllers shall be field tested for self-recovery mode upon power failure. VFDs and DDC controllers shall not reset to manufacturer default programming. Self-recovery mode shall be set to project programming.

j. System Acceptance / Commissioning:

1) General: The system installation shall be complete and tested for proper operation prior to acceptance testing for the owner's authorized representative.

2) As-Built Documentation: After a successful acceptance demonstration, the contractor shall submit as-built drawings of the completed project for final approval. After receiving final approval, supply PDF files of as-built drawing sets, together with AutoCAD files on flash drive to the owner.

3) Operation and Maintenance Manuals: Submit three copies of operation and maintenance manuals. Include the following:

i. Manufacturer's catalog data and specifications on the front end portions of the system provided by the CCSI.

ii. An operator's manual that will include detailed instructions for all operations of the front-end portions of the system.

iii. A programmer's manual that will include all information necessary to perform programming functions.

iv. Complete program listing file and parameter listing file for all programs.

v. A copy of the warranty.

vi. Operating and maintenance cautions and instructions.

vii. Maintainable asset list in Caltech template per project transition to operations guidelines.

4) Contractor shall request and obtain the latest approved Cx guide and Asset Management manual from Caltech for full commissioning requirements.

k. HVAC and Control System Tagging and Naming Convention:

1) All asset naming must conform to the latest Caltech asset naming standards, available from Caltech Asset Management. Contractor shall request and obtain the latest approved asset naming standards from Caltech.

l. Training:

1) CCSI shall provide the engineer a customized training class outline that is based upon the site's system layout prior to any scheduled training. On-site pre-canned training classes are not acceptable.

2) Factory trained control engineers and technicians shall provide training sessions for the owner's personnel.

3) The CCSI shall conduct a minimum of two 4–hour training courses for the designated owner's personnel in the maintenance and operation of the front-end system. One class shall be given upon system acceptance and the other approximately six months into the warranty.

4) The course shall include instruction on specific systems and instructions for operating the installed system to include as a minimum:

i. System overview

ii. System operating procedures

iii. Programming procedures

iv. Maintenance procedures

m. Warranty: The control system shall be warranted to be free from defects in both material and workmanship for a period of one (1) year of use and service. This warranty shall become effective the date the owner accepts or receives beneficial use of the system.

n. GUI: Full commissioning and acceptance of the Graphical User Interface at the time of acceptance.

o. Coordination with operations and maintenance as per the project transitions to operations guidelines.

1) Testing, Adjusting, and Balancing is a construction-time process by which the contractor fine-tunes and then proves that the contractually required flow-rates are achieved at each individual device on the project.

p. TAB specification:

1) The contract documents should explicitly define the procedures for the testing, adjusting, and balancing (TAB) of air handling, refrigeration, hot water, and chilled water piping systems and other equipment as the basis of final acceptance. This shall include design conditions, tolerances, and the data to be obtained and documented in the reports submitted for final acceptance.

2) The contract documents shall explicitly identify the limited number of Caltech-approved TAB agencies to perform the testing, adjusting, and balancing under direct contract to the general contractor (i.e., completely independent of the mechanical contractor). The TAB agencies shall specialize in the balancing and testing of heating, ventilating, and air conditioning and shall be accredited by the Associated Air Balance Council (AABC).

DIVISION 26 – ELECTRICAL

Electrical Sustainability Principle

Energy modeling should be performed to support life-cycle cost evaluation during the early design (schematic design and design development) to ensure that the systems selected support the project energy target/goal.

Overall, all projects should maximize energy efficiency and performance to the greatest extent possible given the project scope, budget, and schedule constraints. All projects should emphasize the best available and most efficient technology for generators, controls, and lighting.

All major electrical systems should be commissioned in compliance with Caltech's Smart Commissioning Program (see Commissioning).

Section 26 00 00 – Electrical Systems

1. Design Criteria:

a. Introduction:

1) The following electrical design criteria are to be followed whenever possible except where there is a conflict with any specific building program, in which case the building program shall prevail. For any items not mentioned or addressed either in the design guidelines or project program, the consulting engineer shall use their best judgement in accordance with modern practice and consultation with the Caltech project manager and Caltech electrical engineer.

b. General:

1) The design of electrical systems shall be such that all equipment shall be provided and installed with the highest degree of quality and workmanship in both equipment type and installation.

2) The electrical design shall utilize energy efficient systems and equipment, minimizing operational and maintenance costs.

3) The design of the electrical system shall offer maximum flexibility to any future modification or remodeling without requiring any upgrades to the major electrical distribution equipment.

4) The entire electrical system shall be fully rated, and the interrupting capacity of all equipment and its components shall exceed the available short circuit current rating by at least 10%. Series ratings are not acceptable.

5) All work associated with the installation of electrical equipment shall be accomplished by skilled workers who are experienced and qualified in the type of work that they are to accomplish.

6) All electrical work, including high voltage, such as pulling-in wires and cables, circuit-breaker work, installing electrical devices and disconnect switches, working in electrical panels, and performing electrical connections shall be done by certified electrical journeymen, known and formally documented to be qualified in and experienced in electrical work. All electrical workers who are working on high voltage installations or repair must have successfully passed OSHA 10 and OSHA 30 classes. Additionally, a fluke clamp amp meter or equivalent should always be carried as part of an electrician's tools to check energized conductors capable of withstanding, without breakdown for a period of one minute, the application of a 60 Hz alternating potential between high-voltage, live parts and dead-metal parts, and between live parts of high-voltage and low-voltage circuits. Prior to each use electrical test equipment must be verified to be functional, inspected, and calibrated.

7) Provide life safety measures when and where electrical, fire protection, and fire suppression will be shut down or rendered ineffective during construction. Provide 24–hour fire watch continuously during the shutdown or impairment of system(s) throughout all areas affected by the shutdown. Coordinate all electrical, fire protection, and fire suppression shutdowns or repairs with Caltech Planning, Design & Construction project manager. All shutdowns must be posted at least 48 hours prior to commencing.

8) Any electrical equipment shall have UL certification for its safe and proper installation and use.

9) All shutdowns will have to be coordinated with Electrical Shop and provide at least 2 weeks' notice in advance for complex (buildings) systems or at least 1 week in advance for simple shutdowns (an electrical panel work). Refer to Appendix XVI for the Caltech utility shutdown request form.

10) All work needs to comply with NFPA 70E including but not limited to:

a) PPE
b) LO/TO

c. Codes and Standards:

1) All products (accessories, components, systems, etc.) shall conform to NEMA standards and shall be UL listed for the use specified.
2) When possible, for project uniformity similar products shall be supplied by the same manufacturer throughout the project.
3) All tools, equipment, and work practices shall meet all applicable Cal/OSHA requirements.
4) All work shall comply with:

a) California Electrical Code (CEC), California Building Code (CBC), and all applicable national, state, county, and local codes and standards
b) California Code of Regulations, 8 CCR Subchapter 5, Group 2, "High Voltage Electrical Safety Orders"
c) American Standards for Testing of Materials (ASTM) for Electrical Protective Equipment
d) National Fire Protection Association (NFPA) Article 70

d. Available Services on Campus:

1) Caltech will provide campus utility maps showing the point of connection for utilities and specific sizes of connections within the tunnel system or manhole system closest to the building site under consideration. The primary electrical distribution system is distributed throughout the campus via utility tunnels and/or underground duct banks at 2400 / 4160 / 17,000 volts.
2) Each new building shall provide the necessary secondary unit substation(s) consisting of medium voltage switch(es), transformers, and distribution sections for its connected load.

3) Always leave at least one duct bank conduit for EMERGENCY SPARE. Never use the last duct bank conduit unless it is first replaced.
4) Medium voltage conduits to buildings need to have at least 1 each 5–inch spare conduit.
5) ALL main electrical rooms should have 480–277V and 208–120V systems.
6) Use of TRYSTAR Tap BOX for portable emergency generators.

e. Electrical Rooms, Equipment Sizing and Location:

1) The size and location of electrical rooms shall comply with all applicable codes and provide a safe working environment and easy access for the maintenance crews and operation personnel.
2) All electrical rooms shall be provided with temperature, humidity, and flood alarms. These alarms shall be monitored by the building automation system (BAS).

a) Temperature alarms shall be set at 77°F
b) Relative humidity (RH) alarms shall be set at 30% (low) and 70% (high)

3) Floor-mounted equipment shall be installed on 4" housekeeping pads with 28–day strength concrete of 3500psi. Equipment room floors shall be sloped to drain towards adjacent corridor. Other means of preventing and/or removing water from electrical spaces will be considered.
4) IR windows manufacturer shall provide average transmission value of IR windows and it shall be posted next to IR window. Table of IR targets behind IR window with emissivity ratings shall be posted next to IR window.
5) Main Electrical Rooms

a) Main electrical rooms need to provide redundancy and capacity to the building for future projects.

- Need to be double-ended in a single lineup
- Tie CB shall be located in the middle and normally opened
- Shall have automation to open a main CB and close tie

b) Electric rooms shall have at least one active network port for service and maintenance use.

c). Main electric room shall have one active wall-mounted telephone near main exit.

d). Main electric room shall be provided with wall-mounted as built single line plan of the building electrical system, first approved by the electrical engineer. This document shall be large enough for easy reading (42"W x 30"H) mounted and laminated on ¼" foam board or similar product. It shall be weather sealed to tolerate harsh environment and insects.

e). Main electric room shall have Caltech wireless network coverage to support asset management, preventive maintenance programs, and electrical workers communications.

6) Electrical service shall be sized based on calculated demand load plus a 20% after occupancy spare capacity for future expansion.

7) Specify electrical equipment that minimizes harmonics generation back into the system; this equipment must follow either IEE519 and/or Design Lights Consortium's Technical Requirements V5.0**.**

8) Secondary unit substations shall be located within a secured outdoor equipment yard. An indoor substation shall be located within a dedicated room with access doors placed at opposite ends. Provide adequate ventilation.

9) In a multi-story building, stack electrical rooms from floor to floor one directly over another.

10) Provide between floors of electrical rooms and/or electrical closets the following: 4 each 5.5" openings for future 5" conduits and 5 each 2.5" openings for future 2" conduits.

11) Provide epoxy sealer paints for floors and sealer paint for walls and ceiling for all main electrical rooms. This is to minimize concrete, plaster, or other dust into electrical gear.

12) Use only SEL protection relays when needed in electrical protection systems.

13) Recess electrical panelboards/distribution panels

a) 225A or less shall have 2" conduit to a 15" x 15" x 8" pullbox in the ceiling above
b) 250A to 400A shall have (2 each) 2" conduit to a 15" x 15" x 8" pullbox in the ceiling above
c) 400A to 800A shall have (3 each) 2" conduit to a 15" x 15" x 8" pullbox in the ceiling above

14) All panelboards and distribution panels should have at least 2 spare position breakers at ALL times. These are to be used in case of emergency. The panelboard or distribution board can be expanded in order to use circuit breaker positions.

15) Circuit breakers

a) Rating 100A or more shall have electronic tripping unit instantaneous, short, and long protection settings
b) Rating 300A or more shall include amp readings
c) Shall have incorporated hardware for LOTO

16) Main circuit breakers shall have electronic tripping unit with amp reading and instantaneous, short, and long protection settings.

f. Utilization Voltage:

1) Use 480V for HVAC equipment, elevators, motors, lighting, and other mechanical equipment.

2) Buildings shall have 480V service panels.

3) Use 208Y/120V for receptacles and miscellaneous branch circuits.

g. Installation:

1) Emergency power shall be provided for all code required applications as well as in research facilities at equipment requiring emergency power and in telecommunication rooms, electrical rooms, and generator yards / enclosures.
2) Provide a 208Y/120V, 50A, 1–phase, 4–wire outdoor rated receptacle (Hubbell #CS-6369-M7) at each corner of the building or as further directed by Caltech.
3) Provide at least one 20A, 120V, NEMA 5–20R duplex receptacle every 20 feet in building corridors/hallways for maintenance personnel.
4) Provide at least one 20A, 120V, GFCI, NEMA 5–20R duplex receptacle on each accessible exterior side of building.
5) Provide at minimum three 20A, 120V, GFCI, NEMA 5–20R duplex receptacle independent 20A 120V circuits, at locations where small events will likely take place.
6) Carefully consider providing temporary power (event) receptacles at lobbies, courtyards, and similar locations where temporary power needs will likely occur on an intermittent basis.
7) Fan coils or any other equipment requiring wet-service or causing condensate shall be located outside the electrical rooms.
8) Each new building shall provide means of connecting portable emergency generators for building emergency circuits outside the building premises
9) Locate all utilities conveying water (e.g. waste, vent, AW, AV, DCW, DHW, DHWR, ICW, IHW, IHWR, CHW, HHW, etc.) outside the electrical rooms. Said utilities shall not be located inside the electrical rooms.

h. Work Included:

1) The work to be performed under the contract shall consist of furnishing all materials, equipment, labor, tools, and transportation, as outlined in the specifications and drawings, for the complete and proper installation of the electrical work, together with all miscellaneous items of labor and materials for the proper operation of all systems and devices. This shall also include any other detailed drawings and specifications as may be furnished by Caltech or others during the performance of the work, in explanation of said drawings.
2) All apparatus, conduit systems, etc., shall be installed and interconnected so as to form complete systems as herein specified and shown on the drawings, except only those portions that are specifically mentioned herein or plainly marked on the accompanying drawings, as being installed under another section of the specifications or another contract.
3) The installation and materials necessary to make complete systems shall be furnished, whether or not such details are mentioned in these specifications or shown on the drawings.

i. Drawings:

1) The structural, architectural, electrical, and mechanical drawings form parts of the work to be performed, and the work shall be executed in accordance with these drawings and any detail scale drawings that may be furnished by the owner during the course of the work. This contractor shall examine all structural, architectural, electrical, and mechanical drawings in order to fully inform himself/herself as to the scope and detail of the work that will be required of him/her.
2) In general, the electrical drawings are diagrammatic in nature and indicate the locations of outlets and equipment and the circuit arrangement of the required wiring, and though not necessarily indicating the actual runs of conduit, the drawings shall be followed as closely as proper coordination with the work of other trades and the spaces available will permit. The drawings are not intended to be scaled, and this contractor shall refer to the architectural and structural drawings for dimensions and limitations of the building structure and finish, and to the mechanical drawings for the locations of equipment of those trades requiring electrical service and connections. Any discrepancies, conflicts, or questionable points shall be immediately reported to the owner.
3) Complete drawings and specifications of all trades will be available at Caltech Planning, Design & Construction.
4) Preliminary plans and outline specifications shall include simplified single-line diagram(s) with feeder size including conductors, conduit, and over current protection.

j. Record Drawings:

1) During the progress of the work, contractor shall maintain a complete set of contract electrical drawings with the following information marked neatly in ink:

a) All deviations from the original contract drawings.
b) Information contained on change order drawings.
c) Location and positions of all underground conduits.
d) Diagrams of all connections to equipment.

2) Immediately upon completion of the project, the record drawings shall be delivered to Caltech Planning, Design & Construction.
3) 2–inch and larger conduits burial pictures shall be taken and provided to Caltech for record keeping. Pictures can provide a prospective on how conduits are placed in relation to other utilities.
4) Final job walk shall be completed with Caltech engineers to review work including equipment labels and as-built drawings.

k. Cooperation with Other Trades:

1) The contractor shall so order their work that their progress will harmonize with that of other trades and all work may proceed as expeditiously as possible.
2) Insofar as possible, the work under the contract has been indicated on the drawings in such a position as to suit and accommodate the work of other trades, but the work as indicated is diagrammatic and the correct final position of all equipment and materials cannot be indicated. Therefore, the contractor is hereby made directly responsible for the correct placing of their work and the proper locations and connections of their work in relation to the work of other trades.
3) This contractor shall check with all other contractors so that no interference shall occur and so that grade lines may be established for the work of each contractor. No extras will be allowed by any contractor for changes made necessary by interference with the work of other trades.
4) Work so designated on the drawings or herein specified as being installed by others shall be coordinated, and this contractor shall make all necessary provisions for attaching or connecting their work thereto. They shall set all necessary equipment and shall furnish the other trades with all drawings and directions necessary to enable them to properly construct their work so that the entire system shall operate properly. They shall be responsible for the correctness of their drawings and directions, and make, at their own expense, any necessary changes in the completed work of all trades that result from errors in their drawings or instructions.

l. Codes, Ordinances and Regulations:

1) All work shall be in full accordance with the latest requirements of the local city, county and state electrical codes and ordinances and the National Electrical Code, and Caltech design guidelines. Nothing in the plans and specifications is to be construed to permit work that is not in conformance with these codes and ordinances.
2) All tools, equipment and work practices shall meet with the requirements of Cal/OSHA and NFPA 70E.
3) In cases of conflicts in the requirements of the various laws, ordinances, rules, and regulations bearing upon the performance of the electrical work, the requirements providing the greater safeguard to persons, buildings, and contents shall apply.
4) It is recognized that the code specifies minimum standards. Therefore, when materials, workmanship, arrangement, or construction of superior quality or higher standard is specified on the drawings or specifications, the drawings or specifications shall take precedence. Should there, however, be any direct conflict between the code regulations and the drawings or specifications, the code regulations shall govern.
5) The contractor shall furnish, without any extra charge, any additional material or labor, or both, when required by the compliance with the before-mentioned laws, ordinances, rules, and regulations, and where the work is not mentioned in these specifications or shown on the drawings.

m. Permits and Inspection Fees:

1) The contractor shall pay for and obtain all permits and inspection fees required for the completion of the electrical work under this contract. A copy of the permit shall be given to Caltech Planning, Design & Construction before the work is complete. Upon completion of the work, a copy of the permit, signed by the inspector indicating final approval, shall be delivered to Caltech Planning, Design & Construction.

n. Inspection:

1) All work and materials shall be available for periodic inspection by Caltech Planning, Design & Construction.
2) A representative of Caltech Planning, Design & Construction shall be present on all final inspections made by the authorities.
3) Caltech safety representative can review safety work practices at any time, including the use of PPE, tools, etc.

o. Examining Site:

1) The contractor is cautioned to examine the site and familiarize themselves with existing conditions. They shall compare the drawings with existing conditions, and shall note and include in their bid any and all additional work and material necessary to make a complete installation of all systems.
2) By the act of submitting a bid, the contractor shall be deemed to have examined the site, to have accepted such conditions, and to have made allowances therefore in the preparation of their bid.

p. Closing In Un-Inspected Work:

1) The contractor shall neither allow, nor cause any of their work to be covered or enclosed until it has been inspected, tested, and approved by the owner's representative and the governmental authorities having jurisdiction over this work. Should any of their work be covered or enclosed before such inspections or tests have been made, they shall uncover the work, and after it has been inspected, tested, and approved, shall make all repairs with like materials to restore their work and that of other contractors to its original condition.

q. Excavation, Backfill, and Resurfacing:

1) Excavations shall be made to widths and depths required for proper installation of work. After excavation is complete, elevations shall be noted on the as-built drawings.
2) Backfill materials shall be sound neutral earth materials or sand approved by Caltech Planning, Design & Construction.
3) Backfill shall be executed with care, in not more than 8–inch thick loose lifts of approved materials, properly dampened and mechanically tamped to a density equal to 90% of maximum density obtainable by the ASTM Designation D1557-64T method of compaction.
4) All surfaces removed or damaged by this contractor shall be replaced to the satisfaction of Caltech Planning, Design & Construction.
5) After completion of backfill and compaction, the contractor shall have soil tests taken, as required by the owner, to establish that the density required in paragraph 3 above has been obtained. A copy of the soil tests shall be furnished to Caltech Planning, Design & Construction.

r. Sleeves, Inserts, and Openings:

1) The contractor shall be responsible for the proper locations and sizes of all sleeves, inserts, openings, etc., required in the building structure to accommodate their work and shall furnish the proper information to the general contractor so as to avoid cutting or drilling.
2) Where cutting is necessary to install work under this section, it shall be done using methods that will not damage the structure and shall be subject to the approval of the owner. Patching and repair work shall be performed to the satisfaction of Caltech Planning, Design & Construction.

s. Enclosures, Barricades, and Protection:

1) The contractor shall furnish and place proper enclosures, barricades, or guards, as required by Cal/OSHA, and other applicable codes, that are necessary to secure life and property and for prevention of accidents.

2) The contractor shall be responsible for any damage to any of their work included in this specification before final inspection of their work. They shall securely cover all openings into the systems, and all apparatus, equipment, and appliances, before and after being set into place, to prevent obstructions in the conduits and the breaking, misuse, or disfigurement of the apparatus, equipment, or appliances.

3) The contractor shall thoroughly protect all finished floors, walls, equipment finishes, and any other portions of the building, walks, and any or all improvements to the site from damage caused by performance of their work or by carelessness of their workers.

4) All forms of protection shall be such as will be deemed safe and sufficient by the owner. The intention of the contract is that upon completion, the entire work will be delivered to Caltech Planning, Design & Construction in proper, whole, and unblemished condition.

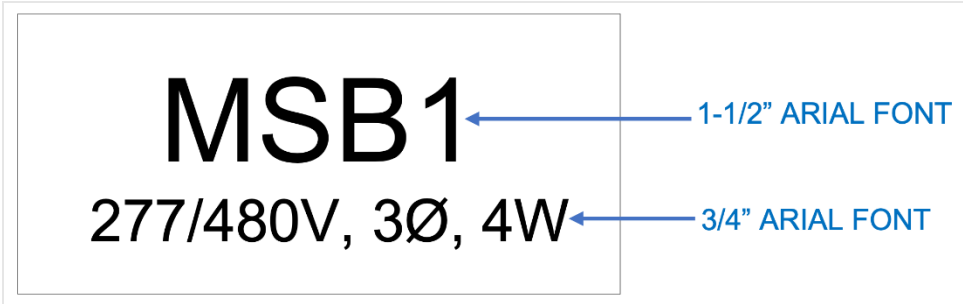
t. Marking of Equipment and Devices:

1) In addition to manufacturer nameplates, all equipment (including but not limited to panels, switchboards, motors, motor control centers, pullboxes, manholes, feeders, splice boxes, VFDs, transformers, inverters, switches, capacitors, etc.) provided shall be furnished with engraved nameplates, tags, and/or other identification method described below.

a) Equipment labels shall have engraved plastic name tags with WHITE background and BLACK letters. Emergency equipment shall have engraved plastic name tags with RED background with WHITE letters.

(1) The first line shall contain the actual equipment name as indicated in the as-built drawings with 1½–inch letters (I.e. MSB1)

(2) The second line shall contain the equipment rating with ¾–inch letters (i.e. 480V/277, 3Ø, 4W)



b) Equipment accessories such as circuit breakers shall have engraved plastic name tags with WHITE background and BLACK letters.

(1) The line shall contain the equipment name as indicated in the reference drawings with ½–inch letters (I.e. TR1A)



c) Emergency equipment shall have engraved plastic name tags.

2) Provide wire markers/labels on each conductor in panelboards, pullboxes, outlet and junction boxes, and at load connections.

3) Complete circuit number shall be marked on all outlets, junction boxes, gutters, switches, controllers, motors, and appliances. Marking shall be done with vinyl / nylon labeling tape. Use 3/8–inch tape with 0.145–inch characters for outlets and junction boxes and 3/4–inch tape with 1½–inch characters for all other marking. Surfaces shall be thoroughly cleaned before applying tape. Labels shall match the final as-built drawings provided.

4) All conduits for signal systems shall be color coded with 6–inch wide spray paint for every 10 feet length as follows:

(1) ORANGE Security

(2) LIGHT GREEN Tel / Data

(3) LIGHT BLUE HVAC / Building Automation System (BAS)

(4) RED Fire Alarm

5) All power and lighting distribution switchboards, power, and lighting panels and panelboards, motor control centers, and gutters shall be marked with the complete feeder circuit number, voltage, and phase, and location of feeder overcurrent device.

6) Busways shall be marked at each cable tap box, every 20–foot run of busway and at each branch circuit breaker or fusible bus plug.

7) All switches and circuit breakers shall be labeled to indicate the load served and its location.

8) Provide warning signage as required by code. Signs shall be permanently mounted with cadmium plated steel screws.

9) Nameplates shall be mounted with steel screws.

10) Provide a full-size glass frame photocopy of the single line diagram in the main electrical room.

11) Where identification is necessary for the proper and safe operation of the equipment, the marking shall be clearly visible and illuminated.

12) A coded identification system shall apply to all circuits, carrying low or high voltage power, control, supervisory, or communication.

13) Upon completion of work for new or modified panels, contractor shall install type as-built panel directories in each panel within the manufacturer provided directory holder. The directory shall clearly identify all circuits to their clear, evident, and specific purpose or use. Each circuit identity shall include sufficient detail to allow each circuit to be distinguished from all others per NEC, or CEC where adopted, Article 408.1 and 408.4. Handwritten directories are unacceptable. Copies of as-built panel schedules shall be placed in panel directories. Electrical contractor to include all costs required for larger-than-standard custom panel directory holders to accommodate copies of as-built panel schedules.

14) All medium voltage and life safety (emergency) conduits exposed or concealed in shafts or above ceilings shall be identified with markers at a distance not to exceed 10’–0” O.C.

u. Equipment Provided By Others:

1) Equipment provided by others and installed and connected by this contractor will be delivered to them at the building. They shall examine the equipment and determine whether or not it is in proper condition to be installed. They shall, within 48 hours, notify Caltech Planning, Design & Construction in writing, in the event of damage or missing parts or accessories that would affect the proper installation or connection of the equipment.

2) If any such equipment is not delivered prior to the final completion, the electrical services shall be terminated as directed by Caltech Planning, Design & Construction.

v. Connections to Equipment:

1) All electrical outlets, apparatus, motors, equipment fixtures, wiring devices, and appliances that require electrical connections, whether they are furnished under the electrical work or not, shall be fully connected in a manner approved by Caltech, to the corresponding electrical system.

2) Where the work under this section required connections to be made to equipment that is furnished and set in place by others, the contractor shall obtain such roughing-in dimensions from the manufacturer or supplier of each such item or equipment and the contractor shall assume fully the responsibility for the neat and workmanlike installation of the connections thereto.

3) This contractor shall be responsible for the installation of the low voltage wiring required for the air conditioning system.

w. Field Work Orders:

1) Before any work is started for revision or extension of work to the contract drawings, a field work order is to be obtained and signed by Caltech Planning, Design & Construction representative and a representative of the contractor.
2) All demolition projects shall include eliminating existing and unused conduits and conductors connected to electrical panel boxes.

x. Third Party Tests:

1) The contractor shall make such tests as may be required by the owner. Tests of the complete installation shall be made with all fixtures and other appliances connected and operating to demonstrate the successful operation of the various systems. The contractor shall furnish all test equipment, temporary wiring, and all labor required to make these tests. No tests shall be made except in the presence of Caltech Planning, Design & Construction representative.
2) Any defective workmanship or materials disclosed by any test shall be removed by the contractor and replaced with new at their expense and tested to demonstrate its compliance with these specifications.
3) The wiring shall be tested for grounds in accordance with the latest edition of the National Electrical Code, to demonstrate that all of the designated outlets have been connected to the correct circuit, that the designated control has been secured, and that all circuits receive current. Motors shall be tested for correct direction of rotation prior to operating any equipment driven by any motor. Verify direction of rotation with the mechanical contractor or other responsible parties.
4) Feeder and power circuits No.8 AWG and larger shall be tested with a "Megger" from each conductor to ground and between conductors. Readings shall be recorded and a copy of these "Megger" readings shall be delivered to Caltech Planning, Design & Construction within 24 hours of the testing. Megger readings shall comply with the IEEE/ANSI ATS 2017.
5) Electrical panels shall be tested for rotation and proper phasing before their loads are to be connected.
6) Caltech standard rotation is clockwise (A, B, C) and shall be tested and mark at the building service entrance and at electrical panels.
7) Electrical feeder insulation shall be tested, as may be required by the Caltech electrical engineer.
8) Test reports shall be provided to Caltech electrical engineer within 7 days of completed testing.

y. Workmanship per NECA/ANSI standards:

1) Only workers with experience and technical qualifications shall perform the work to install the products specified.
2) The installation shall be performed in a neat and workmanlike manner.
3) Any work that, in the judgment of the owner, is not installed in a neat and workmanlike manner, shall be removed and replaced to the satisfaction of and without cost to Caltech.
4) Unused conductors shall be removed from all conduits.

z. Materials and Equipment:

1) All materials and equipment used in the electrical work herein specified shall be new and suited to the use intended, except where otherwise indicated or as directed by Caltech, and shall be delivered to the job in original, unbroken packages.
2) All materials and equipment shall be listed by Underwriters Laboratories or equally recognized authorities.
3) Any products judged not in accordance with these specifications will be rejected.

aa. Substitutions:

1) The contractor shall note that for certain items, the names of selected manufacturers have been specified, and the words "or approved equal" have been omitted. For such items, all bids shall be based on the use of the product specified, and only such products shall be submitted for approval.

2) Where the words "or approved equal" are used, the product of one or more manufacturers is specified. Substitutions may be submitted for approval as an alternate to the item specified, along with the cost difference between the item specified and the proposed substitution.

3) No substitution of materials or equipment will be allowed without approval prior to bid. Approval must be confirmed in writing. Any non-approved materials or equipment found on the job shall be removed and replaced. All secondary costs arising from the use of such materials and equipment shall be paid for by this contractor.

bb. Guarantee:

1) Contractor shall furnish to Caltech a manufacturer's guarantee on all material under this contract furnished by the contractor and a written guarantee on all work performed under this contract for a minimum period of one year after certified substantial completion.

cc. Service Outages:

1) During construction, all existing services to adjoining occupied areas are to remain in full service up to the point of changeover and connection to existing services.

2) Service outages of completed areas necessary for changeover and construction shall be scheduled in advance with the owner's representative as to the time and duration necessary for the outage. The owner's representative will arrange the outages with all concerned parties.

3) Where the changeover and connection to an existing or established service will cause a service outage for a period of time that is unacceptable to the owner's representative, a temporary connection, at no cost to Caltech, shall be made to supply service to the area affected until the permanent service can be restored.

dd. Hazardous Materials

1) Contractor shall dispose of all materials in a manner that meets all federal, state, and local regulations, and furnish to Caltech a manufacturer's guarantee on all material under this contract furnished by the contractor and a written guarantee on all work performed under this contract for a minimum period of one year.

ee. Not Negotiable: Except where written approval by the Caltech electrical engineer is provided, the items noted below are considered as non-negotiable requirements and must be performed as stated in this section of the Caltech design guidelines.

1) Outdoor electrical equipment/enclosures shall have no top penetrations.

a) In order to avoid future water leakage/seepage into the equipment, all outdoor equipment/enclosures shall not have penetrations on top of the equipment.

2) SF6 and/or oil switches and/or protection equipment are not allowed.

a) All switches and protection equipment shall not contain SF6 and/or oil.

3) Aluminum conductors/cables are not allowed.

a) All conductors and cables shall be made of copper.

4) Transformers with aluminum windings are not allowed.

a) All transformer windings shall be made of copper.

5) Motors ≥5 horsepower, without a variable frequency drive (VFD), are not allowed.

a) All motors ≥5 horsepower shall be provided with a VFD.

6) Multiwire branch circuits are not allowed.

a) 120V and 277V circuits must have dedicated neutral.

7) No feed through GFCI.

a) Equipment requiring GFCI protection shall use independent GFCI receptacle or GFCI circuit breaker.

8) 120V receptacles on single yoke shall be of a single circuit.

a) 120V duplex receptacles shall not be fed by two different circuits.

Section 26 05 00 – General Requirements for Electrical Systems

Impact Investigation: The contractor shall be responsible for planning, coordinating, and executing all electrical shutdowns and project impact investigations required for work throughout the construction phase. The contractor shall coordinate investigation access and shutdown activities through the Caltech PM. The contractor shall prepare and review impact investigation findings, shutdown procedures, and outage mitigation measures with the Caltech PM and Electrical Shop prior to implementation. The contractor shall be responsible for maintaining continuity of operations and providing any required temporary or backup power necessary to support construction activities, occupied spaces, research operations, and critical systems. Costs associated with temporary or backup power shall be included as part of the project.

26 05 13 Medium Voltage Cables

1. Introduction:

a. All primary distribution cabling design and installation shall meet the Caltech campus medium voltage (MV) distribution system standards.

b. All work associated with the installation of MV cables shall be performed by cable installers/splicers who are knowledgeable, skilled, and regularly engaged in the performance of such work and who have had at least seven years' experience in the "cable splicer" classification and at least five years' experience with this type of cable.

c. Each reel of cable provided shall be recently manufactured, less than 12 months, and shall bear a tag containing the name of manufacturer, insulation type, and year of the manufacture.

2. Codes and Standards:

a. All cables shall conform to the current standards, including but not limited to Insulated Cable Engineers Association (ICEA), Association of Edison Illuminating Companies (AEIC), and be UL listed.

b. All cable splices shall be 15kV rated. Cable splices shall be constructed per IEEE #404 1986 standard.

3. General:

a. All primary 2,400V cables shall be minimum 5kV, 500Kcmil shielded, single copper conductor.

b. Cables shall be MV–105 with ethylene propylene rubber (EPR) insulation, jacketed, and triple tandem extruded.

c. Insulation shall be high quality EPR based, 115 mils minimum average thickness, and not less than 115 mils at any point, 133% insulation level, and 5kV class.

d. Jacket shall be 80 mils minimum average thickness, polyvinyl chloride (PVC) jacket extruded over the metallic shielding tape.

e. Metallic shielding tape shall be an uncoated copper tape, helically applied over insulation shield 5 mils thick with minimum 12.5% overlap.

f. Conductor shall be soft, round, copper, concentric Class B stranded per ASTM B–8.

g. No cable shall be installed until the cable pulling and tension calculations are approved.

4. Installation:

a. Prior to installation of cables, the ducts or conduits shall be mandreled and swabbed with a Caltech approved pulling compound that is to be submitted with the cable shop drawings. The pulling compound shall be applied liberally and continuously during the pull.

b. No cable shall be installed until the cable pulling and tension calculations are approved by Caltech.

c. The lubricant shall not affect the volume resistivity of semi-conducting jacket or insulation shield present.

d. Provide one 600V insulated #4/0 copper ground conductor.

e. The contractor shall use the utmost care in loading, unloading, removing lagging from reels, setting up, pulling, etc., so that the cables will not be damaged or subjected to any bends less than the minimum recommended by the manufacturer. All this work shall be done in the presence of Caltech's representative.

f. Installation of the cable shall be done in the presence of Caltech's representative with 24 hours' notice, in writing, of any and all installations.

g. The cables shall be pulled into the ducts using a pulling eye made from the conductor of each individual cable so that all pulling strain is imposed on the cable alone. In no case shall any form of cable grips be used over the cable insulation and jacket.

h. In making the pulling eye, the conductor shall be turned back on itself making a suitable eye and the ends served onto the main conductor, making a tight mechanical bond to withstand the pulling strap. This section shall be wrapped tightly with tape to present a smooth surface. After the cable has been successfully pulled, the pulling eye and conductor shall be cut off and discarded up to not less than 3 inches of the undisturbed insulation. Alternate methods are subject to the approval of Caltech.

i. The three single conductor cables shall be pulled into the ducts simultaneously with standard types of equipment used for pulling purposes. Once the pulling of cables has started, it shall be continued to completion in one pull.

j. Splices, terminations, and stress relief cones shall be made by Caltech approved qualified cable splicer. Shielding shall be grounded. No independent length of cable shall be left with the shielding ungrounded. Splicing and termination work shall be done in the presence of Caltech's representative. Caltech shall be notified of schedule for splicing and terminations before any work is started.

k. Splices, terminations, and stress relief cones shall be constructed in accordance with the cable manufacturer's recommendations. Details of these recommendations shall be submitted to Caltech for approval before any work is started.

l. The contractor shall test cables and appurtenances after the installation is complete. Such tests shall be made with all electrical apparatus disconnected. The contractor shall furnish an approved test engineer and suitable equipment capable of reading the currents and providing the voltages required to make a D.C. high-potential test on the completed cable installation. Cable manufacturer shall recommend the potentials to be used in testing and the procedures to be followed.

m. Cables must be tested within 48 hours after installation. It shall be the responsibility of the contractor to notify Caltech's representative when any installation will be completed and make all arrangements to assure that this requirement is complied with.

n. Results of the tests shall be furnished to Caltech's representative.

o. Each cable shall be identified in every manhole, pullbox, or tunnel where it appears with a permanent marker indicating phase "A", "B," and "C", feeder number, origination, and all termination points, as the case may be.

p. All cables not in conduit or duct shall be supported on Kindorf brackets and Kindorf porcelain cable clamps or Caltech approved equal.

q. Lugs shall be properly terminated and crimped per manufacturer recommendations.

r. All lugs must be fastened and secured with rated bolts, washers, and nuts with the required torque.

s. Bolts' torque shall be documented and provided as part of the as-built drawings.

t. Medium voltage cables terminating into electrical equipment shall be equipped with IR windows capable of spotting terminations.

v. Provide at all medium voltage connections (splices, switches, etc.) removable deadbreak elbows with incorporated test point. Elastimold splice (P/N K656I–W0X) or approved by electrical engineer.

26 05 19 Low Voltage Electrical Power Conductors and Cables

1. Introduction:

a. All conductors for secondary power and lighting distribution system shall be new with 600V insulation rating.

b. Wire and cable in the 600V class shall be delivered to the project in unbroken packages and each package shall bear the UL and manufacturer's labels showing the date of manufacture and maximum allowable voltage. All wire and cable shall be copper.

c. All conductors shall be installed in conduit. MC / AC cable is not an approved wiring method unless specific written approval is obtained from the Caltech Planning, Design & Construction project manager.

2. Codes and Standards:

a. All conductors delivered to jobsite shall bear the UL label and manufacturer's labels indicating the date of manufacture and voltage rating.

b. Wire and cable as manufactured by one of the following companies will be acceptable:

1) Houston Wire & Cable Company; Rome Cable Corporation; Triangle Wire & Cable, Inc.; Carol Cable Company, Inc.; Southwire Company; ExCel Wire and Cable Company; American Insulated Wire Corporation.

3. General:

a. All conductors shall be copper and be stranded unless noted otherwise.

b. Minimum conductor size for lighting and power shall be No. 12 AWG.

c. Minimum conductor size for control wiring shall be No. 14 AWG.

d. The insulation of cables used for branch circuits shall be single dual rated cable THWN/THWN–2:

e. The insulation of cables used for feeders shall be type XHHW.

f. The cables used for fire alarm system shall be as follows:

1) Size No. 14 AWG minimum for horn/bell and smoke detector power circuits.
2) Size No.16 AWG minimum for alarm initiating circuits.

g. Conductor Color Coding and Identification shall be as follows:

CONDUCTOR COLOR CODING TABLE

Conductor	480Y/ 277 Volts	208Y / 120 Volts
Neutral	Grey	White
Phase A	Brown	Black
Phase B	Orange	Red
Phase C	Yellow	Blue
Ground	Green	Green

h. All branch circuits shall be provided with a dedicated neutral conductor.

i. Multi-wire branch circuits are not allowed.

4. Installation:

a. Prior to installation of cables thoroughly clean out all conduits and wireways.

b. Cables shall be lubricated with listed pulling compound during pulling. The cables shall be swabbed with a Caltech approved compound that is to be submitted with the cable shop drawings. The pulling compound shall be applied liberally and continuously during the pull.

c. All feeder cables to transformers, panels, motor control centers, and bus ducts shall be black and color coded with colored plastic adhesive tape in all junction or pullboxes, panels, etc.

d. Joints in wire No.8 AWG and smaller shall be made with 3M Scotchlok, or approved equal, solderless spring connectors. Joints in No.6 AWG and larger shall be made with Burndy Type KS, or approved equal, split bolt solderless connectors.

e. All motor connections shall be made up with one-hole compression lugs and bolts of the proper size and length.

f. All branch circuits shall be marked in panelboards with identifying circuit numbers. All feeders shall be marked in the switchboard, all pullboxes, and panels. Markers shall be T&B EZCode wire markers or Caltech approved equal.

g. Phasing of power panel bus bars shall be left bus phase “A”, center bus phase “B,” and right bus phase “C” facing panel front.

26 05 26 Grounding and Bonding of Electrical Systems

1. Codes and Standards:

a. All bonding and grounding procedures and methods used shall conform to the current codes and standards. Any and all electrical equipment having a metal enclosure shall be grounded.

b. All products used shall be UL listed for the application.

2. General:

a. Grounding and bonding conductors shall be soft-drawn stranded copper conductors.

b. Buried or concealed joints shall be made by exothermic welding. All such joints shall be inspected and approved by the Caltech representatives before concealment.

c. System grounding conductors shall be a minimum of No. 4/0 AWG unless otherwise indicated and shall be continuous without joints or splices.

d. Electrical continuity to ground metal raceways and enclosures, isolated from the equipment ground by use of non-metallic conduit or fittings, shall be provided by a green insulated grounding conductor of approved size within each raceway connected to the isolated metallic raceways or enclosures at each end.

e. Ground connection plates shall be 4–hole, Burndy Type YGF29–4N, O-Z Type VG24–4, or equal.

f. Ground rod electrodes shall be ¾–inch diameter by 12 foot long copper weld, copper-clad, or equal. Provide Cadweld to all ground connections. Rods shall be driven to a depth of not less than 8'-0". Electrodes shall have a resistance to ground of not more than 1 ohm if practicable. If the resistance exceeds 1 ohm, two or more electrodes connected in parallel shall be provided until grounding is below 1 ohm.

g. Ground rod clamps shall be cast bronze body providing high pressure contact between rod and ground wire, Copperweld Type AB, Burndy GKP, or equal.

h. Provide a minimum of 100' size 4/0 stranded bare copper conductor in the footing to provide for a base conductor or UFER ground for the electrical system. At each end bond out to a ¾–inch x 10–foot copper clad or copper weld ground rod. At each of these points, provide an inspection or test point and document location on the as-built drawings.

i. The main service ground bus shall be bonded to the cold-water line with minimum of 1–inch conduit with 1 No. 4/0 wire. All metallic piping systems (gas, fire sprinkler, etc.) shall be bonded to the cold-water line with ¾–inch conduit with 1 No. 8 wire.

j. Provide ground bars in all electrical and communications rooms. Ground bars (ground buses) shall be copper with required insulators and stand-offs by Cadweld (Erico Products, Inc.) or B-line. Connect grounds for all telecommunication rooms to the main telecommunication room ground only. This ground system shall be isolated from any other grounding systems except for the single connection at the main system ground.

k. All grounding conductors shall be green, except for isolated ground conductor, which shall be green with yellow stripe.

l. Make good contacts at all panels, outlets, and junction boxes, wherever the conduit run is broken, and permanently and effectively ground all conduits, fixtures, motors, and other equipment and apparatus installed and/or connected under this section of the specifications.

m. Provide grounding for all ECT flooring.

n. Grounding shall be tested by an independent third-party firm with the successful results demonstrated to Caltech staff.

26 05 33 Raceways and Boxes for Electrical Systems

1. General:

a. All wiring inclusive of signaling and low voltage systems shall be in conduits and raceways.

b. Minimum conduit size will be ¾–inch, except for conduit for low-voltage systems, which shall be 1–inch minimum. Verify size requirement before using minimum size.

c. Provide insulated throat for all couplings and connectors.

d. Rigid aluminum conduit shall be used for wiring within areas exposed to magnetic field.

e. Outlets in exposed wet and/or hazardous locations shall be cast ferrous alloy conduit bodies, and in concealed location shall be sheet steel boxes with galvanized finish.

f. Outlet boxes that are installed in concrete floor slabs shall be cast ferrous alloy type listed for installation in concrete.

g. Light fixture outlet boxes shall be equipped with fixture-supporting devices, as required by the unit to be installed.

h. Use solid gang switch outlet boxes for three or more switches for mounting behind a common single plate.

i. Surface mounted power raceways shall be Wiremold 3000 series as required. On a case-by-case basis, with Caltech PM approval, dual channel Wiremold 4000 series may be used. Anodized aluminum finish is required on all locations.

j. Where surface raceways are installed over flush-mounted boxes for cable entry, the opening in the raceway shall be sized to the full opening of the flush-mounted box.

k. Electrical floor boxes shall be flush-mounted such that the entire box is flush with the finished floor.

2. Conduits:

a. Galvanized Rigid Steel (GRC): Standard weight steel that is hot-dipped galvanized both inside and out with threaded steel connectors and couplings.

b. Electrical Metallic Tubing (EMT): Electro-galvanized thin-wall steel electrical metallic tubing. Fittings and couplings shall be steel screw type indoors and compression type in vivarium areas and all other areas where required by code.

c. Flexible Steel Conduit: Manufactured from single strip steel, galvanized prior to conduit fabrication. Connectors and couplings shall be single screw compression or set screw type only.

d. Flexible Liquid-tight Steel Conduit: Liquid-tight conduit shall be manufactured from single strip steel, galvanized prior to conduit fabrication, and shall be provided with an extruded polyvinyl chloride cover.

e. PVC: Heavy wall polyvinyl chloride schedule 40 conduit with solvent welded joints. Use of PVC shall be limited to underground installations at site, encased in concrete (encasement is required for high voltage and feeder circuit cabling, and data and telecom backbone cable only).

e. Grounding: All conduits shall have a green ground conductor sized per NEC requirements

3. Boxes:

a. Sheet steel boxes shall be standard one-piece knock-out boxes. The minimum size shall be 4 inches square by 2 1/8 inches deep with adequate space for devices, wires, and 30% spare fill capacity.

b. Telephone, data, and intercom outlets shall be a minimum of 4–11/16 inches square by 2 1/8 inches deep.

c. Fire Alarm boxes shall be 4 inches square with plaster rings to suit type of device.

4. Installation:

a. Use of galvanized rigid conduit (GRC) shall be in accordance with the following:

1) Where subject to moisture and weather.
2) Where exposed and subject to damage.
3) For all bends and offsets in underground runs or in block walls.
4) In areas where other type of conduit are not permitted.

b. Use of electrical metallic tubing (EMT) is restricted to indoor service and can only be used above suspended ceilings, in metal wall studs, and in areas above 8 feet above finished floor where not exposed to damage for lighting and convenience receptacle branch circuits only and fire alarm system.

c. Use of flexible steel conduit is restricted to final connections to recessed light fixtures, where structural conditions prevent the use of EMT, for final connections to motors and vibrating equipment. Maximum length shall not exceed 6 feet.

d. Flexible metal conduit shall be permitted in concealed space of finish walls or ceilings, where installation of EMT is extremely difficult. These matters need to be referred to and approved by Caltech electrical engineer prior to proceeding with the work.

e. Use of liquid-tight flexible conduit is restricted to final connections to motors and vibrating equipment in areas exposed to weather and all mechanical rooms. Maximum length shall not exceed 36 inches.

f. Use of PVC conduit is restricted to below grade installations. All runs shall be encased with 2500 psi concrete to an envelope of a 3–inch radius larger than the conduit size.

g. Provide sleeves and chases where conduits pass through floors or walls. All sleeves shall be fire sealed in accordance with the fire rating of the wall or floor.

h. Provide PVC coated galvanized steel elbow from underground PVC to ground level.

i. Provide minimum of two (2) 1–inch spare conduits to each corner of the building from main electrical room. Underground conduits shall be extended minimum of 5 feet beyond the building and terminated in a planter or landscaped area for easy future access. Spare conduits shall be terminated into pullboxes with cover exposed above grade. Tags shall be installed at both ends indicating termination points.

j. All signaling and telecommunication system conduits shall be extended from wall outlets to the corridor ceiling void and/or cable tray.

k. Refer to Section 27 00 00 – Communications for additional requirements pertaining to conduits and pathways for data communications installations. Communication pathways installed by electrical contractors must meet the more stringent guidelines as defined in the Communications sections.

l. There shall not be more than the equivalent of 270 degrees of bend between pull points, for example, conduit bodies and boxes for communication cables. Follow manufacturer's requirements regarding the bend radius of the data cables. Maximum number of allowable bends for conduits and raceways containing other electrical cables shall be equivalent to 360 degrees of bend total.

m. At least one pullbox, junction box, or manhole / handhole is required within a maximum length of 100 feet of straight, horizontal conduit run.

n. Provide minimum 2ea. 5–inch spare conduits for the medium voltage feeders, one per medium voltage feeder.

o. Provide at main electrical room at least 2ea. 2–inch spare conduits for building controls and communications from the nearest building and/or as requested by Caltech.

5. Outlet and Junction Boxes:

a. Provide boxes in the wiring or raceway systems wherever required for pulling wires, making connections, or mounting devices or fixtures. Each box shall have the volume required by code for the number of conductors enclosed in the box.

b. Boxes installed in wet locations or outdoors shall be the cast metal hub type, manufactured by Crouse-Hinds, Appleton Electric Co., or approved equal, complete with gaskets and covers. Boxes in other locations shall be galvanized, sheet steel knock-out type manufactured by Raco, Bowers, or Caltech approved equal.

c. Sheet steel boxes, unless otherwise indicated, shall not be less than 4 inches square and 1½" inches deep. Boxes installed for concealed wiring shall be provided with suitable switch or plaster rings as required by the devices to be served. Where the boxes are surface mounted, they shall be fitted with suitable raised or blank covers.

d. Outlets shall be generally installed in the locations shown, but the contractor shall study the general building plans in relation to the spaces surrounding each outlet in order that their work may fit the other work required by these specifications. Boxes shall be installed in a rigid and satisfactory manner by means of wood screws on wood, expansion shields on masonry, or machine screws on steel work.

e. Recessed boxes in stud partitions or suspended ceilings shall be supported with galvanized steel box hangers of types made specifically for the purpose or attached directly to support structure members.

f. Use outlet boxes serving fixtures or devices as pullboxes wherever practicable. In finished areas, provide pull or junction boxes only as indicated or directed.

g. Unless otherwise indicated, all wall outlet boxes shall be flush mounted in areas with finished walls.

h. Use solid type ganged boxes where required for more than two devices.

i. Boxes used in concrete, masonry, or tile shall be of the type designed for use in those installations.

j. Switch and plaster rings shall be such that they are flush to no more than 1/8 inch behind the surface of the finished wall or ceiling.

k. The mounting height of wall outlets shall be measured from the finished floor to the center of the wall outlet. Unless otherwise indicated, the mounting heights of the wall outlets shall be as follows:

Convenience receptacle	18 inches
Switch for light control	48 inches – to top of black box
Receptacle over counter or bench	48 inches – to top of black box
Telephone or data line outlet	18 inches
Thermostat, fire alarm manual station	48 inches – to top of black box

6. Pullboxes:

a. Pullboxes shall be installed in all conduit runs wherever indicated or where necessary, in order to facilitate the pulling of wires or cables, or as required to comply with Code requirements.

b. All pullboxes shall be constructed of code gauge steel and sized as indicated on the drawings or required by code. Pullboxes shall be provided with removable covers secured by machine screws.

c. Wire barriers are called for within pullboxes; they shall be constructed of code gauge steel and securely fastened to the back and sides of the box in order to provide a rigid separation between areas within the box. Exposed edges of the barriers shall be free from sharp edges.

d. All surfaces of boxes and covers, inside and out, shall have a rust inhibitor prime coat and baked on gray enamel finish coat.

7. Wireways:

a. Furnish and install wireways of the sizes indicated on the drawings. Wireways shall be hinge cover and shall be constructed and installed so that electrical and mechanical continuity of the complete wireway system is secured.

b. Wireways shall be manufactured by Square Circle AW Products Co, or Caltech approved equal.

26 05 36 Cable Trays

1. Cable tray shall consist of steel galvanized ladder type, NEMA Class 12C, minimum 6 inches deep by 12 inches wide.

2. Securely fasten cable trays to structural members.

3. System shall use standard prefabricated elbows, reducers, crossovers, tees, and elevation change tray sections as required.

4. Provide fire barriers where cable trays penetrate fire rated building components. Fire wall penetrations must be sealed with an approved design-tested fire-stopping system installed in accordance with manufacturer's instructions.

5. Provide nameplates every 25 feet of the length of cable tray to indicate the type of cables.

6. Provide a bare copper #2 American Wire Gauge (AWG), insulated copper ground conductor in each cable tray. Connect each section of cable tray to the ground connector.

7. Use expansion connectors where required.

8. Install warning signs and label cable types at 50–foot centers along cable tray, placing them so they are readily visible.

9. Trays may be supported by cantilever brackets, trapeze, or individual rod suspension. Supports shall be installed on five-foot centers maximum. A support shall be placed within two feet on each side of any connection to a fitting.

10. Distribution power panels should not be located in or near the voice/data equipment rooms or cable trays. At a minimum, distribution power in adjacent space should be no closer than 3 feet.

11. Transformers should not be located in or near the voice/data equipment rooms or cable trays. At a minimum, transformers in adjacent space should be no closer than 6 feet.

12. Power feeds of greater than 220 volts should not be run parallel to the cable tray. Parallel runs of greater than 20 feet require a minimum separation distance of 18 inches.

13. All power feeds crossing the path of the cable tray at right angles should be a minimum of 6 inches in distance from the cable tray, in order to prevent problems with high-speed data transmissions.

14. There must be a 12–inch separation between the cable tray and the light fixtures. Deviation should be brought to the Caltech PM's attention.

15. A minimum of 12–inch access headroom shall be provided and maintained above the complete cable tray system. Cable trays must have adequate side access for initial cable installation and for future cable adds, moves, and changes.

26 05 43 Underground Ducts and Raceways

1. Underground conduits without concrete encasements shall be PVC coated galvanized rigid steel. PVC schedule 40 may be used where indicated on the drawings or where approved by Caltech.

a. Refer to Section 27 00 00 – Communications for additional requirements pertaining to conduits and pathways for data communications installations. Communication pathways installed by electrical contractors must meet the more stringent guidelines as defined in the Communications sections.

2. Concrete encased underground conduits shall be installed in accordance with the recommendations set forth in NEMA Bulletin No. TCB2–1976.

3. Provide concrete encasement for conduits as indicated and detailed on the drawings. The concrete shall have a minimum compressive strength of 2,500 psi and shall be red in color.

4. During construction, partially completed duct lines shall be protected from the entrance of debris such as mud, sand, and dirt by means of suitable conduit plugs. As each section of a duct line is completed, a testing mandrel not less than 12 inches long with a diameter ¼–inch less than the inside diameter of the conduit shall be drawn through each conduit, after which a brush with stiff bristles shall be drawn through until the conduit is clear of foreign particles. Conduit plugs shall then be immediately installed.

5. Conduits shall terminate in end bells where duct lines enter manholes or handholes.

6. Conduit spacers for duct banks shall be the plastic interlocking type and shall be placed at not more than 5–foot intervals along the duct bank. Spacers shall be secured to prevent movement of conduits during the pouring of concrete.

7. Changes in direction in the duct banks shall be accomplished by using long sweep bends with a minimum radius of curvature of 20 feet or manufactured sweeps with a 150–inch radius.

8. Extend underground conduit that is stubbed out for future use a minimum of 5 feet clear beyond building foundations, concrete walks, paving, other utilities, and the like. Keep underground conduits a minimum of 10 feet clear of future building locations where indicated. Leave ends of underground stub-outs 6 inches clear of concrete envelope. Plug ends of conduit and cover with sand and redwood for mechanical protection. Exact locations of stub-outs shall be indicated by a brass marker at finished grade and on record drawings.

9. Use rigid steel conduit for stub-ups and risers to grade from other conduits. Cap all stub-ups for future use.

10. A jet line 500–pound test plastic pull line shall be installed in all empty conduits in underground duct banks and in all conduits in signal duct banks.

11. Furnish and install a 6–inch–wide, polyethylene, red underground barrier type, with metallic strip / conductor, 12 inches above full length of concrete reading "CAUTION ELECTRIC LINE BURIED BELOW."

12. Where unground conduits penetrate building exterior use "LINK SEAL" for sealing the opening.

13. Manholes and Handholes:

a. Furnish and install manholes and handholes as indicated on the drawings. The manholes and handholes shall be the precast type complete with traffic covers, ladders, pulling irons, sumps, cable support racks, etc., as detailed on the drawings.
b. Manholes and handholes shall be placed on a 6–inch base of compacted sand or gravel to assure uniform distribution of soil pressure on the floor.
c. Surfaces between sections of manholes and handholes shall be cleaned and gasketed and watertight. All outside surfaces shall be coated with an approved waterproofing compound.
d. The tops of manholes and handholes shall align with the finished surfaces where they are installed.

26 05 48 Vibration and Seismic Controls for Electrical Systems and Equipment:

1. All electrical systems shall be designed to seismic design category E.

2. Provide seismic bracing per latest applicable codes and FM Global for all electrical systems and equipment suspended more than 12 inches from the structural support system above.

3. Powder-actuated inserts are not allowed.

26 05 73 Power System Studies

1. Short Circuit / Coordination Study and Arc Flash Hazard Analysis (under all operating conditions)

a. The electrical contractor shall furnish a short circuit and protective device coordination study and arc flash hazard analysis as prepared by the electrical equipment manufacturer or an approved electrical engineering firm.

b. The studies shall include all new distribution equipment supplied by the equipment manufacturer for the project as well as all directly affected existing distribution equipment at the project facility.

c. The short circuit and coordination study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399, ANSI/IEEE 141, and ANSI/IEEE 242.

d. The arc flash hazard analysis shall be performed per the requirements set forth in NFPA 70E – Standard for Electrical Safety in the Workplace. The analysis shall be performed according to the IEEE 1584 equations that are presented in NFPA 70E–2004, Appendix D.

e. Qualifications:

1) The short circuit and protective device coordination study and the arc flash hazard analysis shall be conducted under the supervision and approval of a registered professional electrical engineer skilled in performing power system studies. The registered professional electrical engineer shall be a full-time employee of the equipment manufacturer or the approved engineering firm.

f. Submittals for Review / Approval:

1) The short circuit and protective device coordination study and the arc flash hazard analysis shall be submitted to the design engineer prior to receiving final approval of the electrical equipment shop drawings and /or release of equipment drawings for manufacturing.

2) The results of the studies and analysis shall be presented in a report that shall include the following:

a) Executive summary
b) Descriptions, purpose, basis, and scope of the study.
c) Tabulations of all circuit breakers, fuses, and other protective devices verses calculated short circuit duties.
d) Tabulation of protective device: manufacturer, amp rating, mode #, cat #.
e) Protective device time current curves.
f) Fault current calculations.
g) Details of the incident energy and flash protection boundary calculations.
h) One line diagram.
i) Tabulation of recommended trip setting for circuit breakers for correct coordination.
j).The implementation of any recommendations affecting design issues or other change recommendations identified in the report shall be up to Caltech.
k) Computer model.

3) An evaluation of the arc flash hazards shall be made to mitigate identified hazard level category 3, 4, and dangerous to a lower level.

g. Computer Analysis Software:

1) The studies shall be performed using the latest version of the SKM System Analysis Power Tools for Windows (PTW) software program.

2) Electronic copy of the computer model shall be provided to Caltech for its records.

h. Field Adjustment:

1) Calibrate protective device settings according to the tabulated recommended values provided in the coordination study. Field adjustments shall be made by the NETA certified contractor under the start-up and acceptance testing portion of the project contract.

i. Arc Flash Labels:

1) The contractor of the arc flash hazard analysis shall provide a 6–inch x 4–inch thermal transfer type label of high adhesion polyester for each equipment location analyzed. Labels shall be machine printed with NO FIELD MARKINGS.

2) The labels shall clearly indicate WARNING—Arc Flash and Shock Hazard — Appropriate PPE Required.

3) Labels shall include the following information (at a minimum):

a) Equipment designation
b) Nominal operating voltage
c) Flash hazard boundary (inches)
d) Hazard risk category
e) Incident energy value
f) Working distance
g) Limited approach distance (inches)
h) Restricted approach distance (inches)
i) Prohibited approach distance (inches)
j) Minimum PPE requirements — (e.g., arc-rated long sleeve shirt and long pants or arc-rated coverall, hard hat + balaclava + arc-rated face shield + safety glasses + hearing protection)

k. Engineering Report Number and Issue Date

1) Arc flash hazard warning labels shall be provided on each of the following:

a) For each panelboard — one (1) per panelboard
b) For each motor control center — one (1) per MCC
c) For each VFD — one (1) per VFD
d) For each standalone motor starter — one (1) per motor starter
e) For each low voltage auto/manual transfer switch — one (1) per switch
f) For each low voltage distribution switchboard — one (1) per switchboard
g) For each low voltage switchgear — one (1) per bus section
h) For each low voltage separate distribution disconnect switch — one (1) per switch
i) For each medium voltage switchgear — one (1) per bus section
j) For each medium voltage fused /non-fused disconnect switch — one (1) per switch

l. Labels shall be field installed by the electrical contractor responsible under the start-up and acceptance testing portion of project contract.

Section 26 10 00 – Medium Voltage Electrical Distribution

26 11 10 Outdoor Electrical Pad Mounted Equipment

1. General

a. Provide pulling underground vault for all pad mount equipment

26 11 16 Secondary Unit Substations

1. General

a. Provide double-ended substation with two separate 2400 volt circuits from campus distribution system. The entire system shall be of unit construction with all parts designed, manufactured, and assembled by a single manufacturer to assure complete and proper coordination between all items.

b. Manufacturer: Square D, EATON, GE, or Caltech approved equal.

c. The unit substation construction and installation shall meet seismic zone 4 or seismic design category E requirements.

d. Provide vibration isolators on all floor mounted transformers. Isolators shall be Mason Type ‘BR’ or equal for minimum 0.2–inch static deflection.

e. Outdoors secondary units are not allowed.

2. High Voltage Section:

a. Air-insulated type fuse switch, 5KV, 3–pole.

b. The close and latch (fault closing) rating of the switch shall be 40,000 amperes asymmetrical.

c. Switch shall meet ANSI C37–20 and NEMA SG–5.

d. Surge arrestors shall be installed on the load side of the switch before the fuse.

e. Provide interlock key to guard high voltage section and to interlock with low voltage section.

f. Medium voltage switches shall be equipped with IR windows capable of spotting primary and secondary terminations.

3. Transformer Section:

a. Dry type cast coil for indoor location. Less flammable liquid filled for outdoor location.

b. 80/115 degree C rise for dry type. 55/65 degree C rise for liquid filled type.

c. High voltage windings shall be delta connected. The secondary shall be wye connected.

d. Four full capacity 2½% taps, two above and two below.

e. Both HV and LV windings shall be of copper conductors.

f. Unless otherwise specified, the transformer sound levels shall meet NEMA, ANSI, and IEEE standards, but not exceed 65 dB.

g. Provide a complete forced-air cooling system to increase capacity by up to 33% to 50% minimum.

h. Provide limited short circuit current contribution of 15kAIC on 208–120V systems and 20kAIC on 480Y/277V systems.

i. Provide IR windows capable of spotting primary and secondary terminations.

j. Provide all transformers with K factor 13.

4. Distribution Section:

a. Low-voltage section shall meet ANSI C37.20.1, ANSI 37.51, and NEMA SG–5.

b. Square D Power-Zone IV draw-out type utilizing master pact NW type power circuit breakers with Micrologic 6.0P or equal by EATON and GE.

c. Bus bars and connection shall consist of silver-plated copper mounted on heavy duty glass polyester support. Provide bus compartment barrier.

d. Provide circuit monitoring equipment for each main breaker. Square "D" circuit monitor CM–2350, Cutler-Hammer "IQ–DP 4000" or equal.

e. Main breakers and tie breaker shall be interlocked to prevent paralleling of incoming primary source. Circuit breaker trip units shall be microprocessor based with true RMS sensing, LSIG, breaker open/close status, zone selective interlock, and amps metering. Square D Micrologic Type 6.0A trip unit, EATON, GE, or Caltech approved equal.

f. Compression lugs for cable connections and side barriers in cable compartment.

g. Provide with IR windows capable of spotting primary and circuit breakers ≥ 200 amps terminations.

5. Metering Section:

a. Power meters shall be installed in secondary unit substations on the low voltage side with a 15A circuit breaker and networked with the Caltech Energy Management System.

b. Electro Industries Nexus 1500+ V2 or Schneider Electric METSEPM8244 power quality meters shall be installed in each designated building's main panel boards. The electric meters shall measure line currents and neutral currents, line-line voltages, line-neutral voltages, real power, apparent power, reactive power, current harmonics, voltage harmonics, and demand power values, where applicable.

c. Electric Meter shall have BMS connectivity.

Section 26 20 00 – Low Voltage Electrical Distribution

26 22 00 Low Voltage Transformers

1. General purpose and distribution dry type transformers shall be constructed and tested in accordance with American National Standards Institute (ANSI) and National Electric Manufacturer's Association (NEMA) standards in addition to other requirements specified by the Caltech electrical engineer, if any. They shall, without damage, withstand for two cycles the

maximum fault current, which will occur with a bolted fault at the secondary terminals and with an infinite bus on the primary side.

2. Transformer shall be low loss type with minimum efficiencies per DOE–2016 plus Energy Star when operated at 35% of full load capacity. Transformer shall be Energy Star labeled.
3. Insulation: NEMA Class H, 115 degree C rise over a 24–hour average ambient temperature of 40 degrees C and all Class H materials.
4. Core and Coil: Dried and resin impregnated while under vacuum. Transformers 500KVA and less, 600V primary and less, shall be UL listed and bear the label.
5. Both primary and secondary windings shall be of copper conductors. All bussing shall be copper.
6. All transformers shall have the secondary neutral brought to the terminal section for the option of multiple taps. Transformers shall be equipped with five total 2½% (2 above and 2 below normal voltage) taps.
7. Sound levels shall meet NEMA TR–27 and not exceed the following:
    a. 0–9 KVA 40 dB
    b. 10–50 KVA 45 dB
    c. 51–150 KVA 50 dB
    d. 300 KVA 55 dB
    e. 500 KVA 60 dB
8. Transformers for nonlinear loads shall be K–13 rated, equipped with 200% neutral and double sized neutral terminal.
9. Transformers 15KVA and larger shall be mounted on a 4–inch-high concrete housekeeping pad.
10. Manufacturer's test reports on each transformer shall be given to Caltech Planning, Design & Construction.
11. Final connections to transformers shall be made with rigid conduit terminating with a minimum of 12 inches and not exceeding 36 inches of flexible conduit to the transformer case below the transformer core. Wire or conduit shall not come in contact with the transformer core or its mounts.
12. Provide vibration isolators on all floor-mounted transformers. Isolators shall be Mason Type 'BR' or equal for minimum 0.2–inch static deflection.
13. Wall-mounted transformers shall be mounted with approved load mounts to prevent transmission of vibration to the walls on which they are mounted.
14. Dry type transformers shall be manufactured by Square D, EATON, GE, or Caltech approved equal.
15. Provide limited short circuit current contribution of 15kAIC on 208–120V systems and 20kAIC on 480–277V systems
16. **Equipment Labels:** Shall be provided with equipment nameplates as described in 26 00 00 – Marking of Equipment and Devices
17. Transformers ≥50kVA shall be equipped with IR windows capable of spotting primary and secondary terminations.
18. Outdoor Transformers shall not contain perforations on top to prevent future water leakage.
19. Transformer impedance shall not cause the arc flash to exceed 2.

26 24 00 Switchboards and Panelboards

1. **Panelboards**

a. All distribution and lighting panelboards shall be located indoors, in dedicated electrical rooms or closets. They may be installed in corridors near lab entries only. Do not install panelboards inside laboratory, office, and/or workspaces where they could be obstructed.

b. Furnish and install circuit breaker panelboards of the size, voltage, phase, wires, and rating as indicated on the drawings. Panelboards shall be of the dead-front type and shall be in accordance with the Underwriters Laboratories standards for panelboards and enclosing cabinets, and so labeled.

c. Panelboard boxes shall be of galvanized sheet metal with ample gutter space in accordance with the National Electrical Code. Fronts shall be of flat sheet steel finished in ASA #61 gray enamel over a rust inhibitor, unless otherwise noted. Doors shall be attached with concealed steel hinges and provided with a cylinder tumbler-type combination catch lock and circuit directory. Fronts shall be for either flush or surface mounting as indicated on the drawings. Flush mounted fronts shall be finished with a prime coat in lieu of ASA #61 gray enamel. Boxes shall be 20 inches minimum wide and 5¾ inches deep.

d. Interiors shall be factory assembled and be of the unit type, mounted on a back-plate properly formed to provide a rigid assembly to protect against damage during handling or installation. The structure shall be designed and assembled so that units can be easily replaced without disturbing adjacent units or bus structure, and without field machining of connection strap or panel bussing. Panel bussing shall be arranged to provide sequence phasing; that is, adjacent poles shall be of unlike phases and rotated in sequence. A removable barrier pan shall be provided over the branch circuit breakers to provide easy access to the wiring. Provide main circuit breaker as indicated on the drawings. All lugs shall be of the solderless, anti-turn front-removable type and shall be located at the top or bottom of the panel, as indicated on the drawings. The neutral bar shall be full capacity and shall be located on the opposite side of the panel from the main lugs or breaker.

e. Conductors shall have phase sequence in alphabetical order A, B, C (from top to bottom or from left to right).

f. 120/240 volt, 208Y/120V, 480Y/277V protective devices in panels shall be Square D, EATON, GE, or Caltech approved equal of bolt-on type. Rating and number of poles shall be as indicated on the drawings. Two and three pole breakers shall have one handle. Top of panel shall be 6 feet 6 inches above finished floor.

g. Upon completion of work for new or modified panels, contractor shall install panel directories in each panel within the manufacturer-provided directory holder. Panel directories are to be typed; handwritten directories are unacceptable. The directory shall clearly identify all circuits to their clear, evident, and specific purpose or use. Each circuit identity shall include sufficient detail to allow each circuit to be distinguished from all others per NEC, or CEC where adopted, Article 408.1 and 408.4. Copies of as-built panel schedules shall be placed in panel directories. Electrical contractor to include all costs required for larger-than-standard custom panel directory holders to accommodate copies of as-built panel schedules.

h. Equipment Labels: Panels shall be provided with equipment nameplates as described in 26 00 00 – Marking of Equipment and Devices

i. 120/240 volt, 1 phase, 3 wire and 208Y/120V, 3 phase, 4 wire panelboards furnished under this section of the specifications shall be Square D, EATON, GE or Caltech approved equal. 208Y/120V panelboards shall have a minimum 225 amp bus with maximum of 60 circuits, integrated symmetrical short circuit rating of 22,000 amperes or as required in the arc flash studies.

j. 480Y/277V, 3 phase, 4 wire panelboards furnished under this section of the specifications shall be Square D, EATON, GE or Caltech approved equal. 480Y/277V panelboards shall have a minimum 225 amp bus with maximum of 60 circuits. Symmetrical short circuit current need to be calculated and the minimum shall be actual short circuit current contribution (i.e., Upstream transformer) plus 25% of the actual short circuit current contribution or as required in the arc flash studies.

k. **All panelboards** shall be provided with 25% spare capacity after all loads have been taken into consideration in regard to load capacity and circuit breaker space.

l. **All panelboards** shall be provided with three (3) 1" spare conduits into the nearest accessible ceiling space for future use. All circuit breaker shall be bolt on, installed vertically at the top or bottom of the panel.

m. **All busses** including ground(s) and neutral shall be copper.

n. **All panelboards** shall be equipped with a ground bus.

o. In addition to regular ground bus bar, provide an isolated ground bus bar for all 208Y/120V panelboards when applicable and/or requested.

p. Panelboard covers shall be piano style, door-in-door type.

q. **Surge Protection Equipment**

1) All distribution panelboards shall be provided with an integrated Type 2 Surge Protective Device.

r. All bolted connections (i.e. lugs) shall be torqued to manufacturer's specifications. Mark the torqued bolted connections to indicate it has been torqued.

s. All circuit breakers greater than 125A shall be equipped with electronic solid state tripping device.

2. Switchboards and Distribution Boards

a. General:

1) The entire switchboard shall be of unit construction with all parts designed, manufactured, and assembled by a single manufacturer to assure complete and proper coordination between all items.
2) Manufacturer: Square D, EATON, GE, or Caltech approved equal.
3) Construction and installation shall meet seismic Zone 4 and/or seismic design category E requirements.

b. Switchboards and distribution boards shall be installed indoors.

c. Codes and Standards:

1) The design of all current carrying devices or parts of switchboards shall conform to the standard specified in the related sections of Underwriters Laboratories (UL) No. UL-891 and National Electric Manufacturer's Association (NEMA) Standard PB-2, except as these characteristics may be modified here.

d. Enclosure:

1) The switchboards shall be floor mounted, self-supporting, dead-front and rear, front operated, front connected, distribution type, manufactured complete with all parts, fittings and equipment, including busses, circuit breakers, barriers, terminals, wiring and connections.
2) All switchboard sections shall be a minimum of 24" deep and shall be constructed of code gauge steel.
3) All switchboard sections shall line up evenly, front and rear.
4) All wiring gutters shall extend the full length and depth of the switchboard.
5) All busses including ground and neutral shall be copper.
6) Switchboard shall be capable to increase the number of circuit breakers for future applications. Provide at least 35% additional space.

e. Over-Current Protection Devices:

1) Provide Insulated case circuit breakers for 1600A or larger ratings.
2) Provide molded case circuit breakers for 1200A or smaller ratings. The molded case breakers shall be bolt-on type.

3) The breaker shall meet applicable NEMA AB-1 Standard and shall have a UL label showing UL tested interrupting rating equal to or exceeding the fault current calculated available.
4) Series rated circuit breakers are not acceptable.
5) All circuit breakers greater than 125A shall be equipped with electronic solid state tripping device.

f. Installation:

1) Switchboard shall be mounted on 4" high housing keeping pad. Size of pad shall be as required to meet the minimum edge distance requirement of anchor bolts.
2) Switchboards and distribution boards ≥ 1200 amps shall have power quality meters installed with a 15A circuit breaker. The power quality meter shall be Schneider Electric METSEPM8244. The meter shall measure line currents and also neutral currents, where applicable.

g. Surge Protection Equipment

1) All switchboard and distribution boards shall be provided with an integrated Type 2 Surge Protective Device.

h. All circuit breakers ≥ 100 amps shall be equipped with settings (i.e. instantaneous overcurrent, time delays, etc.) so that they can be adjusted as needed in the future.

i. Equipment Labels:

1) Shall be provided with equipment nameplates as described in 26 00 00 – Marking of Equipment and Devices.
2) Shall have arc flash warning/danger labels with appropriate values.

j. Switchboards and distribution boards shall be equipped with IR windows capable of spotting main and circuit breakers ≥200A terminations.

k. All bolted connections (i.e., lugs) shall be torqued to manufacturer's specifications. Mark the torqued bolted connection to indicate it has been torqued.

3. Motor Control Centers (MCC):

a. General:

1) The use of a motor control center should be the last resort since motors today are often controlled by VFDs. Consult with Caltech electrical engineer prior to using a motor control center.
2) The motor control center shall be of unit construction with all parts designed, manufactured, assembled, and tested by a single manufacturer to assure complete and proper coordination between all items.
3) Motor control centers shall be located indoors only, in the same equipment room(s) and/or area serving the associated mechanical equipment.
4) All motor control centers shall be furnished with minimum of two spare combination breaker/starter units with size "I" starter. The starter bucket shall be complete with all associated devices and components stated below. In addition, minimum of 33% space shall be provided in each MCC for future starters.
5) The motor control center shall be provided with copper bussing.
6) Manufacturer: Square D, EATON, GE, or Caltech approved equal.

b. Enclosure:

1) Structure shall be totally enclosed, free-standing, vertical sections joined together to form one assembly.
2) Buses: All buses shall be silver-plated copper.
3) Motor control center interrupting rating shall be at least 42,000A or as indicated on the drawings.
4) Wiring Spaces: Provide each structure with two horizontal wiring spaces, one at top and one at bottom.
5) MCC construction and installation shall meet seismic zone 4 requirements.

c. Starters:

1) Starter units shall be combination type with components and wiring readily accessible for ease of maintenance, connected to vertical bus by self-aligning connectors.
2) Motor starters shall be the size and type and rated for the short-circuit current available and the service to be performed and conform to all applicable requirements of National Electric Code (NEC), National Electrical Manufacturers Association (NEMA), and California Electrical Code (CEC).
3) All starters shall be complete with the accessories necessary for operation. All starters shall be horsepower rated, with solid state overload protection in each phase leg.
4) Starters for motors ≥ 5HP shall be VFD or VSD.
5) All starters shall be furnished with indicating lights for "RUN", "STOP," and "TEST" modes.
6) All starters shall be furnished with auxiliary contacts for future connections or interlocks.
7) Each magnetic motor starter shall be equipped with a "hand-off-auto" heavy duty selector switch in the cover and a 120V operating coil.

d. Combination Breaker Starter Units:

1) Combination motor starters shall conform to all the requirements for magnetic starters, plus have a circuit breaker circuit protective disconnect in the same enclosure conforming to the National Electrical Code requirements for the motor operation.
2) The combination starter unit disconnect shall be of the high-speed instantaneous magnetic trip motor circuit protector type, designed to suit motor characteristics.

e. Installation:

1) Mount motor control center on 4–inch-high concrete housekeeping pad. Pad shall be the size of the base of switchboard plus space for at least one future section or larger where more than one future section is indicated on the drawings. Bolt equipment securely to pad.
2) The top of handles shall not exceed 6 feet 6 inches above finished floor regardless of the pad height.
3) Provide spare fuses for each size and type installed on the project.

f. Equipment Labels:

1) Shall be provided with equipment nameplates as described in 26 00 00 – Marking of Equipment and Devices

a) MCC name per drawings
b) Source identification per drawings
c) Voltage rating

2) Shall have arc flash warning/danger labels with appropriate values.

g. Equipment Manuals:

1) Equipment manuals shall include single-line diagrams and control circuit diagrams to support troubleshooting at a later time.
2) MCCs shall be equipped with IR windows capable of spotting main and bucket terminations ≥200A.

h. All bolted connections (i.e., lugs) shall be torqued to manufacturer's specifications. Mark each torqued bolted connection to indicate it has been torqued.

26 25 00 Low Voltage Enclosed Bus Assemblies

1. Plug-In Busway:

a. General:

1) Busways shall not be used for building power distribution. They may be used for specific applications in laboratories and/or shop spaces. Consult with Caltech electrical engineer prior to using busways.

2) If plug-in busway is installed, it shall be weatherproof.

b. Furnish and install a plug-in busway system complete with plug-in cable tap boxes, end closures, hangers and plug-in devices as shown on the drawings.

c. Ampere rating, voltage, and phase of busway shall be as indicated on the drawings. Neutral bus, where indicated, shall be full capacity.

d. The busway shall consist of copper bus conductors totally enclosed and supported in a sheet steel housing. The complete installation shall be coordinated throughout, rigid in construction, of uniform size and neat and symmetrical in appearance.

e. The busway shall be a 5–wire system.

f. Busway, fittings, plug-in devices, and accessories shall bear the UL label.

g. Busway system shall be Square D, EATON, GE, or Caltech approved equal.

h. Equipment Labels:

1) Shall be provided with equipment nameplates as described in 26 00 00 – Marking of Equipment and Devices.

a) Switch Name per drawings

b) Voltage rating

2) Shall have arc flash warning/danger labels with appropriate values.

26 27 26 Wiring Devices

1. Switches:

a. Wall switches shall be fully enclosed, quiet-operating flush toggle type switches for back and side wiring, rated 20A, color to be selected. Hubbell #HBL–1221 for single pole and #HBL–1223 for three ways.

b. Illuminated switches (light on with load off) shall be quiet type, 20A, Hubbell #HBL–1221–IL.

c. Ganged switches on 277V circuits shall have a barrier between each switch.

2. Manual Wall Box Dimmers:

a. Fluorescent dimmers shall be 120V (or 277V) as required for circuit wiring. Rating shall be based on quantity of lamps controlled. Lutron “Nova T” series, NTF–10.

b. Incandescent dimmers shall be thin-profile 120V and up to 1500 watts rating. Lutron “Nova T” series, “NT–1000 or NT–1500,” color same as switches.

c. Wallbox dimmers shall be slider type with built-in switch and radio/TV interference filter. Dimmers shall be solid-state type.

d. Manual dimmers shall be installed in individual outlet boxes. Do not install in ganged boxes with other devices.

3. Occupancy Sensor Switch:

a. Wall sensor switch shall be infrared type. Watt Stopper Model # WI–200 or equal.

b. Ceiling sensor switch shall be infrared type corner mounted. Use Watt Stopper Model #WPIR corner mounted for small room. Use Model #CI–200 for rooms larger than 300 square feet.

c. Ceiling sensor control unit (switch pack) shall be in J-box next to lighting circuit junction box.

d. Bathroom and non-occupied area sensors shall be ultrasonic type. Watt Stopper Model # W2000 or equal.

4. **Manual motor control switches** for single-phase motors shall be flush or surface mounted, as required, full-voltage type with thermal overload protection.
5. **Remote control switches** shall be standard duty, momentary contact, push-button or selector switches, equipped with pilot light and jewel, where specified.
6. **Receptacles:**

a. Receptacles shall be NEMA 5–20R, rated 20A, 125V, heavy duty specification grade. Hubbell #HBL 5362 or approved equal.

b. Receptacles shall not be connected for feed through, but pigtailed in box for circuit continuation.

c. Receptacles outdoor or within 6 feet of sink shall be ground-fault circuit interrupter type. Ground fault receptacles shall be 20A, 125V, duplex, three-wire grounding with test and reset buttons, color to be selected. Hubbell #HBL–GF-5362.

d. Provide one isolated ground duplex outlet at each area where there is a telephone/data outlet, when applicable and/or requested. The isolated ground wire shall be used only for other isolated ground receptacle outlet and separate from other convenient receptacle ground wires. The isolated ground receptacle outlet shall be color orange. Hubbell #HBL–IG–5362

e. A maximum of 5 convenient receptacles will be allowed on each 20A circuit. Provide dedicated circuit for all copiers, laser printers, microwaves, and refrigerators. Additionally, provide dedicated circuits for the lab equipment, if requested by users and/or required per equipment manufacturer literature.

f. Receptacle on emergency power shall be color red.

g. In general, mount receptacle vertically with the centerline 18 inches above finished floor and with ground slot at top. At locations with countertop/cabinet, mount receptacle 8 inches above finished countertop or cabinet.

h. Controlled receptacles such as those equipped with occupancy sensors shall be color BLUE with a BLUE wall plate and labeled “CONTROLLED.”

7. **Installation:**

a. Device plates shall be matching plastic for flush installations and matching raised metal covers for surface installations.

b. Where weatherproof wiring devices are shown, cast metal boxes with matching weatherproof cast metal covers and gaskets shall be used.

c. All 125V, 1 phase, 15A and 20A receptacles installed outdoors with direct grade-level access, on roofs and in bathrooms shall have ground-fault circuit-interrupter protection for personnel. This protection shall be provided by using either ground-fault circuit breakers or GFCI receptacles. Each individual GFCI receptacle shall not feed through protection; no daisy chain protection from GFCI receptacles.

26 28 00 Low Voltage Circuit Protective Devices

1. All disconnect safety switches shall be type heavy duty 600 V class and shall meet the latest edition of Federal Specifications W–S–865.
2. All low voltage safety switches with/without fuses shall be similar to “EATON double door safety switches.”
3. Provide all disconnect safety switches with devices enabling the switch to be locked in the open and closed positions.

4. Externally operable disconnect safety switches shall have quick-make, quick-break mechanism, capable of switching ten times the switch rating and with cover interlocks with defeat mechanism for maintenance. Provide switches with number of poles, ampere, voltage and HP rating, types of enclosures, and fusible or non-fusible as indicated and as required for the particular application.

5. Provide National Electric Manufacturers Association (NEMA) 1 enclosures for interior locations and NEMA 3R enclosures for exterior or wet locations unless otherwise indicated. Switches having a dual rating when used with dual element fuses shall have rating so indicated on the metal plate. Fuses, where required, shall be Underwriters Laboratories (UL) listed current limiting type RK5. Enclosures shall be penetrated through the top.

6. Provide molded case, thermal magnetic type circuit breaker in accordance with the following:

   a. Shall be installed in individual enclosures, in panelboards, combination motor controllers, and control panels, with proper voltage rating for point of application.

   b. Trip rating as indicated on the drawings.

   c. Quick-make and quick-break type, with wiring contacts. Provide with arc chutes and individual trip mechanisms on each pole, two and three pole breakers common trip.

   d. Trip-free with trip indication independent of the “on” or “off” positions.

   e. Shall have at adjustable instantaneous pickup that is readily accessible for its adjustment for circuit breakers rated ≥100A.

   f. Shall reduce arc flash level to category 2.

7. Provide a complete set of fuses for switches, panels, switchgear, and control centers as required. Use nonrenewable types only, provide dual element time delay and current limiting type fuses for disconnects in motor circuits and fast-acting type for other applications.

8. Manual motor starter with overload protection shall be installed with all motors ¼ Hp through 3/4 Hp in size where across-the-line starting is used. Provide heater type overload device built into toggle switch for all exhaust blowers or other motor controlled with a toggle switch.

9. When disconnects of 100A and less are provided between a VFD and a motor, the disconnect shall include a “break before break auxiliary contact” that will signal the VFD to start a “coast-to-stop process.” Prior to use, obtain written approval from Caltech Planning, Design & Construction Services.

10. **Equipment Labels:**

    a. Shall be provided with equipment nameplates as described in 26 00 00 – Marking of Equipment and Devices

       1) Switch Name per drawings
       2) Voltage rating

    b. Shall have arc flash warning/danger labels with appropriate values.

26 29 23 Variable Frequency Drives

1. **Variable Frequency Drives (VFD) or Variable Speed Drives (VSD)**

   a. VFDs shall be required for any motor 5 HP and larger. VFDs may also be provided for motors less than 5 HP.

   b. Expose VFD points to the LON or BACNET card as needed.

   c. Hardwire fire life safety interlock to VFD. Fire alarm shutdown shall not be allowed to be done via DDC programming.

d. VFD shall have a 5–year extended warranty for parts and include labor with factory start-up and shall be programmed to include the following features:

1) Inject DC braking on multiple fan arrangements.
2) Self-energize and recover after power disruption.
3) Adjust carrier frequency to minimize motor harmonic noise in the occupied space.
4) Three phase or E-Clipse bypass with service switch / electronic bypass with service switch. Provide bypass feature on equipment without N+1 redundancy.
5) Conventional 3–Phase bypass.
6) 0–10 VDC for speed control.
7) Hardwire input signal for Enable / Disable.
8) Hardwire input signal for status.

e. VFDs shall have the following minimum electrical requirements:

1) Voltage nominal: 120V, 208V, 240V, 277V, and/or 480V phase-neutral and/or phase/phase
2) Frequency nominal: 60Hz
3) Power Factor: ≥0.98
4) Frequency fluctuation: ±5%
5) Voltage fluctuation: ±10% (single phase or multi-phase)
6) Voltage imbalance: ±3%
7) Efficiency: ≥98%
8) Short Circuit current withstand: 100kAIC
9) Voltage and frequency ride-through capability
10) Switching frequency: 8 KHz or above
11) Galvanic isolation
12) Protective functions:

a) Over-voltage
b) Under-voltage
c) Earth-leakage suppression
d) Motor short circuit protection
e) Output and input switch supervision
f) Over-current protection
g) Phase loss detection (line and load)
h) Under-load supervision (i.e., could be used to detect loss of motor belt)
i) Over-load supervision
j) Stall protection
k) Over-temperature
l) Ground fault

13) Output

a) Output frequency: 0 to +500 Hz
b) Frequency resolution: 0.01 Hz
c) Voltage: 0 to 100% supply (input) voltage

14) Ambient operation

a) Temperature: 10° to 40°C
b) Relative humidity: 5 to 95%

15) Compliance Standards

a) UL
b) IEC/EN 610000–3–12
c) IEC EN61800–3

d) UL 508C

Section 26 30 00 – Electrical Power Generating and Storing Equipment

26 32 13 Engine Generators

1. General:

a. Provide complete package generator set, unit-mounted radiator cooling system, UL 141 listed under-base fuel tank microprocessor-based control and monitoring panel, battery and charger, building management system (BMS) communications module, remote annunciator, and walk-in weather protective sound attenuated enclosure.

b. Obtain from one distributer and by single manufacturer. Automatic transfer switches shall be provided by the distributor of the engine generator for single source of responsibility.

c. Emergency generators shall be installed with automatic transfer switch(es) (ATS) from where it receives the signal to start.

d. Generators shall have visible and legible nameplates.

e. The generator set shall be EPA-approved and the contractor shall obtain the operation certification from SCAQMD.

f. Obtain fuel permit requirements from Pasadena Fire Department.

g. Mount on a housekeeping pad in a dedicated yard with a containment area built around to contain any oil or antifreeze spills.

h. Generator output shall be routed to a dedicated distribution switchboard. The switchboard will contain at least 3 fully provisioned spare positions sized to accommodate similar sized ATS.

i. Provide a tap box for connecting a full-sized portable generator. The tap box shall be located on grade with easy access from a portable generator. Connect tap box to the generator switchboard and key interlock switchboard main break with generator breaker.

j. Engine-generator set, components, and enclosure shall meet requirements of seismic design category E without additional external bracing to building structure. Frequency modifying devices are not allowed.

k. Interface with building fire alarm system: Control panel shall incorporate normally open and normally closed contact positions for run condition, fail condition, and battery charger failure.

l. Interface with Caltech EMS.

m. Provide appurtenances for communications to the EMS all indicator and alarms mentioned herein. Include all components necessary to connect to the system including software, software upgrades, network cabling, and other equipment necessary to effectively interface with all monitoring and control points noted herein and on the drawings.

n. Generator exhaust and ventilations shall comply with applicable code requirements and manufacturer's recommendations, including required clearances from grade, building openings, air intakes, and adjacent structures.

2. Operation and Maintenance Manuals:

a. Installation, maintenance, and operating instruction manuals shall include, but not be limited to, the following:

1) 100% accurate system "as-installed" drawings, interconnect diagrams, schematic diagrams, wiring diagrams, individual sub-system component manuals, operation procedures, system description with theory of operation, maintenance schedules and procedures, original programmed settings and parameters, and other information necessary for the owner to maintain, operate, test, and troubleshoot system.

2) The O&M manual shall contain step-by-step instructions for startup and shutdown. The first page shall contain name, address, and phone number of local representative to be called for service or parts. Follow with complete parts lists by actual ordering catalog numbers. O&M manual also shall contain four copies each of test record forms and service

record forms for owner use. Forms shall show proper interval for testing, servicing, and replacing of components, lubrication, filters, antifreeze, etc., including recommended specifications and fluid levels for lubricants.

3) Recommended spare parts list (with pricing) for 5 years of operation.

b. O&M manuals shall not solely rely on sub-component manuals. Thorough consolidation of operating and maintenance information shall be available in system overview guide. Include major components of system in overview.

c. Turn two (2) full sets of manuals over to owner prior to conducting training of owner personnel.

3. Training:

a. Provide training in start-up, operation, and maintenance of equipment supplied using the services of a factory-certified representative of the manufacturer. Provide 2 training sessions of 2 hours minimum each on separate days.

b. Submit training plan for owner's approval. Training plan to include duration of training sessions, suggested class size/attendees, locations, lesson objectives, and outline of training topics.

3. Warranty:

a. Provide 5–year extended warranty against defects in materials and workmanship. Warranty period shall begin after certified substantial completion. Extended warranty shall also include the automatic transfer switches.

4. Acceptable Manufacturers:

a. Engine generator set: Caterpillar, Cummins.

b. Active diesel particulate filter: Rypos or pre-bid approved equal.

c. Exhaust silencer (if required): GTE Industries or pre-bid approved equal.

d. Isolation equipment: Mason Industries or approved equal.

e. Battery charger: Sens, La Marche, Charles Industries, or approved equal.

5. Ratings and Performance:

a. NFPA 110 requirements

1) Class 48 (research buildings): minimum time, in hours, to operate at rated load without being refueled.
2) Class 48 (other buildings): minimum time, in hours, to operate at rated load without being refueled.
3) Type 10 (all buildings): maximum time, in seconds, allowed for the load terminals of the transfer switch to be without acceptable electrical power.
4) Level 1 (all buildings): systems shall be installed where failure of the equipment to perform could result in loss of human life or serious injuries.

b. Engine generator set

1) Altitude 500 feet above sea level in an ambient temperature of 114°F (45.5ºC)
2) Stable frequency regulation

c. Alternator

1) 80% power factor lagging
2) 480V, 3–phase, 60Hz, 4 wire wye
3) Stable voltage regulation from zero to full load less than or equal to ± 0.5%

d. Transient performance

1) Engine

a) Start and load in 10 seconds per NFPA 110, Type 10, and CEC 700.12
b) Accept 100% block load per NFPA 110

2) Frequency regulation ± 0.25% no load to full load. Speed droop shall be adjustable from 0 to 10%, from no load to full load, and share within 5% when paralleled with similarly equipped engines.

3) Alternator

a) 10% @ 50% block load, 20% @ 75% block load, and 30% @ 100% block load or better
b) AC waveform output contains < 5% total harmonic distortion (THD) at full linear load when measured from line to neutral with < 3% in any single harmonic, and no third-order harmonics or their multiples
c) Telephone influence factor < 50
d) Telephone harmonic factor < 3%
e) 300% fault current capability unless selective coordination requirements require otherwise

e. Factory production test certified: NEMA MG1 and IEEE 115

6. Engine:

a. Four-stroke cycle diesel compression ignition at 1800 rpm consistent with engine durability.

b. Displacement: BMEP consistent with engine durability.

c. Water cooled.

d. Fuel type: No. 2 domestic diesel fuel oil. Ultra-low sulfur diesel (NTE 15 ppm).

e. EPA-certified tier 2.

f. Engine accessories:

1) Fuel filter. Parker Racor three-stage coalescing strainer/water separators with manual selector valves, in bowl water sensor probe or equivalent by manufacturer.
2) Fuel cooler. If required, provide fuel oil cooler installed on the radiator and piped by generator manufacturer to cool the hot fuel returning to the day tank. Fuel shall be cooled to below 65°C at all load levels up to its capacity.
3) Lube oil filter
4) Intake air filter
5) Lube oil cooler: Suitable for operation of the generator set at full rated load in ambient temperature specified.
6) Fuel transfer pump
7) Fuel priming pump: Engine driven positive displacement, mechanical, full pressure
8) Gear-driven water pump
9) Alternator to recharge battery when engine is running
10) Crankcase ventilation filters to remove oil mist coming from the engine crankcase breather vent. Filter shall remove 99% of the oil mist and airborne particles. Return oil to engine.
11) Electronic direct fuel injection or have suitable emission control equipment
12) Electric speed sensing governor capable of isochronous regulation.
13) Safety shutoffs for:

a) High water temperature
b) Low oil pressure
c) Overspeed
d) Over cranking
e) Over voltage
f) Emergency power shutoff switches

7. Cooling System:

a. Engine skid mounted engine driven radiator with blower type fan, sized to maintain safe operation at 114°F (45.5ºC) ambient temperature. Temperature shall be measured 10 feet behind engine without engine heat rise. System shall be sized and configured to accommodate an air flow static restriction of 0.5 inches of water at the radiator.

b. Liquid cooled prime movers shall be arranged for closed-loop cooling.

c. Jacket water heater: circulating

1) Maintain engine jacket water to 43°C (110°F) in ambient temperature of –1°C (30°F).

2) Provide water heater systems each designed and tested by manufacture to ensure 10 second starting in minimum ambient temperatures inside weatherproof enclosure; 208V, single-phase, with thermostatic control and oil pressure disconnect switch. Jacket water heater shall be furnished with ball valve shutoffs at the inlet and outlet and factory wired relays to disconnect power during engine operation.

d. Engine cooling system shall be filled with solution of 50/50 mix ethylene glycol at the initial fill.

8. Exhaust System:

b. Furnish exhaust silencer type as required such that the overall generator noise, including noise from enclosure and exhaust pipes, shall be limited to no more than 72 dBA when measured at a distance of 23 feet (7 meters) from enclosure.

1) Mount so weight is not supported by engine
2) Provide flexible exhaust fitting

a. Diesel particulate filter: Active type, powered directly from generator set

b. Condensate traps: Condensation drains shall be automatic and built into the silencer

c. Thermal expansion: Stainless steel connector exhaust flex to accommodate thermal growth and vibration isolation. Size connector to meet project requirements shown on the drawings.

d. Exhaust blankets: Provide flexible insulation blankets on components other than turbo chargers. 1 inch thick, high temperature fiberglass cloth wrap.

e. Acceptable back pressure: Silencer and exhaust pipe shall be sized so exhaust back pressure does not exceed maximum limitations specified by generator set manufacturer.

9. Starting System:

a. Starting system shall be 24VDC with positive engagement drive. Starting motors shall be able to start engine in less than 10 seconds.

b. Include on each engine all controls and magnetic contactors to operate starting motors either manually at the engine or from a remote location.

c. Cycle cranking shall be provided to open and lock out the start circuit after six 15–second attempts to start failed engine start.

d. Battery system:

1) Provide two (2) 24V lead acid, heavy duty type starting battery sets (N+1), minimum 8D rating, designed for this application and duty
2) Furnish batteries having sufficient capacity for 6 cranking cycles (15–second duration each with 15–second rest periods) without need for recharging at 18°F ambient temperature
3) Each starting battery set shall be capable of starting the engine generator
4) Provide vinyl or approved equal coated steel battery rack
5) Battery cables and clamps

e. Best battery selector (BBS):

1) The BBS shall be a passive device consisting of diodes, voltage surge protection, and high current terminals
2) The BBS shall electrically isolate the two battery sets and their respective battery chargers allowing starter motor cranking current to flow in the forward direction and blocking current from flowing in the reverse direction
3) Starters shall be connected to both battery sets through the BBS. Size diodes to conduct 100% of the maximum starter cranking current
4) Size starting batteries to compensate for the power loss across the BBS
5) Complete system shall comply with EGSA 100B–2000, performance standard for engine starting and control batteries

e. Battery charger

1) Two (2) solid state, automatic, current limiting, float type battery chargers for automatically recharging each battery set (one per battery set).
2) Four rate charger: constant current, constant voltage, high rate taper, and float equalized
3) Furnish each charger with the following features:

a) UL 1236 listed and meets NFPA 110 requirements
b) DC ammeter and voltmeter
c) Equalizer timer and fused AC input and DC output
d) Overload protection and reverse battery single phase connection protection
e) Limit recharging time from full discharge to 8 hours maximum
f) Alarm circuits meeting requirements of NFPA 110 for AC fail, low battery voltage, high battery voltage, and battery charger fail, battery fault; with form C alarm contacts for each point
g) Automatic disconnect during engine starting and operation

10. Speed Control: Electronic, no droop isochronous.

11. Alternator:

a. Maximum temperature rise 105°C at 40°C ambient

b. Synchronous type

c. Self-ventilated

d. Drip-proof construction

e. Capable of sustaining 300% overcurrent for 10 seconds under a 3–phase symmetrical short circuit unless selective coordination requirements require otherwise

f. Sub transient reactance limited to less than 12%

g. Insulation: Class H insulation systems

1) UL 1449 recognized
2) Vacuum impregnated with epoxy varnish

h. Permanent magnet brushless excitation (PMG)

i. Rotor

1) Four pole
2) Winding: Random or wet layer wound
3) Varnish process: Epoxy-based material applied to each layer of magnet wire
4) Coil supports: Driven through to ensure permanent alignment
5) End winding spacing
6) Amortisseur windings
7) Bearings: Sealed, single or double

j. Stator

1) Cooling air passages and fan. Space heater to keep the alternator free of moisture.
2) Welded laminations to prevent the cutting of wires
3) Skewed stack to minimize slot ripple on output voltage and produce a smooth voltage waveform
4) Pitch: 2/3 pitch winding to optimize efficiency and minimize total harmonic distortion
5) Varnish process: Two dips and bakes using class H impregnating varnish

k. Alternator components

1) Solid state design digital voltage regulator:

a) +/-0.25% regulation from no-load to full load at steady state with power factor between 0.8 to unity
b) True RMS sensing

c) Over-excitation protection
d) Electronic voltage buildup protection
e) Loss of sensing protection
f) VAR/PF control
g) UL 508A listing, and if applicable UL6200

2) Two 100% insulated case rated circuit breakers. One for building loads and one for load bank.

a) Adjustable long time, long time delay, short time, and short time delay curve shaping elements
b) Shunt trip on load bank breaker for integration with load bank controls
c) Shunt trip on generator breaker for integration with closed transition ATS
d) Ground fault alarm: Monitoring relay for breaker 1000A and above. Relay to be adjustable from 3.8A to 1200A and include an adjustable time delay of 0–10S.
e) Provide ground leakage relay for the entire system to trip the ATS feed and load bank feed circuit breakers.
f) Mounting: Adjacent to, or integrated with, control and monitoring panel.

12. Load Bank Port:

a. Provision for exercising the generator with a portable load bank is required. The load bank circuit breaker previously described shall be "load bank" to allow connecting a portable load bank for maintenance/testing purposes. This breaker shall not have a permanent load connected to it. Its rating should be equal to the main output circuit breaker of the generator. Provide an 18"x18" (typical) port with receptacle/plug/cover/cord proper for the load bank to pass the load bank temporary cable through, during load bank testing. The load bank port shall NOT require opening the generator enclosure door to connect or disconnect the cord.

13. Controls:

a. NFPA 110 compliant

b. Microprocessor based solid state controls to automatically start, protect, and monitor engine-generator set with panel illuminating lighting and digital display.

c. Control panel includes:

1) Electrically operated fuel control
2) Relay to disconnect battery charger during cranking. This can be eliminated if automatically internal to the charger.
3) Switching lamps and meters shall be oil tight and dust tight. All active components shall be installed to within a NEMA 3R enclosure. There shall be no exposed components with door open operating 750V.
4) Control panel to include self-illumination from generator circuit.
5) Programmable protective relays to shut down and lock out the engine on abnormal conditions including:

a) Overspeed
b) Operation of emergency stop switches
c) Overcrank (alarm only when generator serves a fire pump)
d) Low lube oil pressure (alarm only when generator serves a fire pump)
e) High engine temp (alarm only when generator serves a fire pump)
f) Low coolant level (alarm only when generator serves a fire pump)
g) Fail to crank (alarm only when generator serves a fire pump)
h) Dead battery (alarm only when generator serves a fire pump)

6) Monitoring items shall include but not be limited to the following items and control:

a) Coolant temperature
b) Oil pressure
c) Battery voltage
d) RPM
e) Digital voltmeter, 0.5% accuracy
f) Digital ammeter, 0.05% accuracy
g) Frequency meter, 55–65 Hz +/- 0.125 Hz.

h) Running time meter (hours and 1/10 hours). Non-resettable.
i) AC power metering shall be 0.5% accuracy and include frequency, phase, selector switch with real time power metering including, kW, kVA, kVAR, kWh, PF, % of rated load.

7) Control Items:

a) Voltage level adjustment
b) Overvoltage level adjustment
c) Undervoltage level adjustment
d) Over frequency level adjustment
e) Underfrequency level adjustment
f) Four position function switch marked AUTO, MANUAL RUN, OFF/RESET, and STOP
g) 4 NO and 4 NC dry contacts for local and remote alarms, wired to terminal strips
h) Emergency off button (mushroom)
i) Automatic remote start capability
j) Overcrank lockout shall occur after four cranking attempts, except when fire pump called to run when normal power is not present

8) In accordance with NFPA 110, Level 1, the control panel shall provide battery powered individual visual alarm indicator functions at battery voltage and visual and audible pre-alarm:

a) Overcrank
b) Low water temperature
c) High engine temperature pre-alarm
d) High engine temperature
e) Low lube oil pressure pre-alarm
f) Low lube oil pressure
g) Overspeed
h) Low coolant level
i) EPS supplying load
j) Control switch not in automatic position
k) High battery voltage
l) Low cranking voltage
m) Low voltage in battery
n) Battery charger AC failure
o) Lamp test
p) Contacts for local and remote common alarm
q) Spare (x3)

9) Engine shutdown (programmable to accommodate fire pump called to run when normal power not present), with audible alarm:

a) Low oil pressure
b) High engine temperature
c) Overcrank
d) Overspeed
e) Emergency stop switches
f) Overcurrent (circuit breaker trip and lockout)
g) Reverse power
h) Low-coolant level

10) Status report:

a) Engine running
b) Circuit breaker open
c) Circuit breaker closed

d. Provide position contacts at the main disconnect

e. Visual alarm resettable only after fault condition has been corrected

f. Audible alarm shall include silencing circuit, which, after activation, will permit annunciation of subsequent failures.

g. Control panel mounting: Mounted on engine generator set in NEMA 3R enclosure on shock isolators

h. Provide remote annunciator panel:

1) Compliant with NFPA 110 Level 1 requirements
2) Two required
3) Locate one on the exterior of the weatherproof enclosure next to the door into the enclosure and the other at a 24–hour staffed location

14. Vibration Isolators:

a. Required between the structural steel base and sub-base tank

b. Prevent equipment vibrations from being transmitted to enclosure

c. Steel or cast-iron top and bottom housings incorporating one or more steel springs with built-in leveling bolts and built-in resilient chocks to control oscillation and withstand lateral forces in all directions

d. The spring static minimum nominal deflection shall be 3 inches. Each isolator unit shall have independent non-contacting snubbers.

e. Isolators shall be Mason Industries type SLFH series or equal

15. Sub-base Fuel Tank and Appurtenances:

a. Tank size shall be at least 133% the quantity required to support the duration of run per NFPA 110

b. Rating: UL 142 Listed

c. Double wall construction

d. Flex fuel lines (NFPA 110 construction)

e. Epoxy lined to prevent corrosion

f. Tank exterior: Chemically treated, primed, and painted in factory standard.

g. Tank Accessories:

1) Overfill prevention valve on tank fill inlet
2) Visual dial type fuel level gauge
3) Manual gauge port with stick gauge
4) Fuel supply and return ports
5) Atmospheric vent port and mushroom type UL-listed flame arrester vent to be installed onto vent pipe by others
6) Containment tank emergency vent port and pressure relief cap
7) Primary tank emergency vent port and pressure relief cap
8) Digital tank monitor/overfill control panel with pilot warning lights, audible alarm, output contactors, and press to silence/test/reset feature equal to Pneumercator TMS 2000. Provide with analog output option for use by building automation system. Mount inside weatherproof enclosure.
9) Overfill panel with pilot warning light, audible alarm and press to silence/test/reset feature (mounted near tank indoors). Panel shall interface to digital tank monitor.
10) Fill spill box
11) Leak detection
12) Required internal piping and wiring
13) Decals and signs required by code and authority having jurisdiction

16. Weatherproof Enclosure

a. Engine cooling airflow through enclosure with an upturn discharge: Maintain temperature rise of system components within required limits when unit operates at 110% of rated load for 2 hours with ambient temperature at top of range specified in system service conditions.

b. Louvers: Storm-proof and drainable to prevent entry of rain.

c. Interior lights with switch: Factory-wired, vapor-proof type fixtures within housing; arranged to illuminate controls and accessible interior. Arrange for external electrical connection. Provide AC LED lighting system and connection point for operation when remote source is available.

d. Convenience outlets: Factory wired, GFCI. Arrange for external electrical connection.

e. Point of aux power entry: Provide a 100A/2P/120–240V single phase panel, factory wired to battery charger, block heater, enclosure lights, and the receptacle. This is a single point of connection for Caltech maintenance crew wiring. The block heater, battery charger, receptacle, and lighting shall be wired to the panel at the factory, in accordance with the California Electrical Code.

f. Finishes: Manufacturer's standard finish color over corrosion-resistant pretreatment and compatible primer.

g. Hinges and latches: refrigerator style stainless steel.

h. Battery lighting: The enclosure shall be equipped with (2) dual head emergency lights with battery backup power supply, meeting UL 924, NFPA 101, and OSHA illumination standards.

i. The enclosure shall be equipped with exterior emergency break-glass stations, located one per side to shut down the generator. Top of stop switch shall be 48 inches above finished grade. Break-glass station to have sign reading: "EMERGENCY STOP OF GENERATOR."

j. Provide fire extinguisher near interior side of each entry door (two required).

17. Sequence of Operation

a. Upon loss of the normal source voltage at any automatic transfer switch, a signal is to be generated to initiate start of the generator to pick up load within 10 seconds of the signal. The highest priority loads requiring the emergency power shall be connected in the order of their priority. Provide circuitry to prevent the automatic transfer of emergency loads to the bus until there is sufficient capacity to carry the load. Provide equipment, wiring, and programming as required to meet requirements.

18. Acceptance Tests

a. Leak Test (Enclosure, Fuel System, and Cooling System): After installation, charge fuel and cooling systems and test for leaks. Similarly, simulate rain test on the enclosure and test for leaks. Repair leaks and retest until no leaks exist.

19. Post Startup Load Test

a. Jobsite testing shall be conducted after start-up is complete. Start-up shall include battery installation, fuel system, and a general inspection of the exhaust and ventilation systems to ensure proper installation and operation. The generator sets shall then be started, and observations shall be made by a factory trained technician as to proper operation of the engine, generator, generator controls, and all external engine generator support systems. All safety and pre-alarm devices shall be checked for proper operation of the circuit and corresponding indicating lights on the control panel and at the remote annunciator panel, in the presence of the owner and the electrical engineer. Phase rotation shall be checked.

b. During start-up, use resistive reactive load banks sized to match the kW/kVA rating to the engine-generator to calibrate engine generators and paralleling switchgear. Testing shall include cold start, 25, 50, 75, and 100% step loads (slow addition of load to confirm operation), 50% and 100% block loads (instantaneous load percentages), after which an additional 8–hour testing at rated nameplate.

c. Engine-generator set test results are to be certified to comply with specification parameters or necessary corrective actions implemented and tests repeated until compliance is certified at no additional cost to Caltech.

d. Contractor shall provide fuel for testing.

20. Code Compliance Test

a. NFPA 110: After previously described testing, provide full Chapter 7 test with respect to both power output and function in the presence of the approving authority and others as determined at the time.

b. Contractor shall provide fuel for testing.

c. At conclusion of testing, engine-generator set shall be serviced including replacing air, oil, and fuel filters, changing lubrication oil, checking and refilling batteries, adjusting fan belts for proper tightness, refilling of cooling system, and refilling fuel storage tank.

26 33 23 Central Battery Equipment

1. Emergency Lighting Uninterruptible Power Supply (Lighting inverter)

a. UL listed to UL924, Emergency Lighting and Power Equipment

b. Able to work with any type of lighting load (including electronic loads, LEDs, etc.)

c. Built-in self-diagnostic and self-testing capabilities

d. Provide front access for easy battery installation and service

e. Current THD: ≤3%

f. Power factor: 0.98 lead and 0.98 lag

g. Operating voltage: ±10% of nominal

h. Operating frequency: ±5% of nominal

i. Voltage regulation: ±3% of nominal

j. Efficiency: ≥90%

k. Hot swappable batteries

l. Operating Temperature: 20 to 30 degrees Celsius.

m. Relative Humidity: < 95% (non-condensing).

n. Audible noise: <60dBA at 1 meter

o. Alarms: High/Low Battery Charger Fault, Near Low Battery, Low Battery, Load Reduction Fault, Output Overload, High/Low AC Input Volts, High Ambient Temperature, Inverter Fault, Output Fault

p. Communications port: RS–232

q. Network: Remote monitoring and reporting via BACNET/IP, Ethernet TCP/IP, Modbus TCP, Modbus RS485

26 34 00 Electronic Coupled Generators

1. Electronic Coupled Generators (Solar PV, Fuel Cells, Energy Storage, etc.)

a. All electronically coupled generators shall be approved smart inverter/converter type as defined on the CEC website (it has minimum requirements such as for efficiency).

b. All electronic coupled generators shall be required to have:

1) Physical disconnecting mechanism
2) Dedicated circuit breaker at a facility electrical service panel

c. UL1741–SA and/or IEEE1547–2018

d. The smart DER inverters/converters (solar, fuel cells, energy storage) default settings should be set with Caltech electrical engineer's approval.

26 36 23 Automatic Transfer Switches

1) **General**:

a. Provide closed transition automatic transfer switches as described herein and shown on the drawings.

b. Obtain from supplier of engine generator for single source of responsibility.

2) Interface with Caltech EMS:

a. Provide appurtenances for communications to the EMS all indicator and alarms mentioned herein. Include all components necessary to connect to the system including software, software upgrades, network cabling, and other equipment necessary to effectively interface with all monitoring and control points noted herein and on the drawings.

3) Operation And Maintenance Manuals:

a. 100% accurate system "as installed" drawings, interconnect diagrams, schematic diagrams, wiring diagrams, individual sub-system component manuals, operation procedures, system description with theory of operation, maintenance schedules and procedures, original programmed settings and parameters, and other information necessary for the owner to maintain, operate, test, and troubleshoot system.

b. The O&M manual shall contain step-by-step instructions for startup and shutdown. The first page shall contain name, address, and phone number of local representative to be called for service or parts. Follow with complete parts lists by actual ordering catalog numbers. O&M manual also shall contain four copies each of test record forms and service record forms for owner use. Forms shall show proper interval for testing, servicing, and replacing of components, lubrication, etc., including recommended specifications and lubricants.

c. Recommended spare parts list (with pricing) for 5 years of operation.

d. O&M manuals shall not solely rely on sub-component manuals. Thorough consolidation of operating and maintenance information shall be available in system overview guide. Include major components of system in overview.

e. Turn two (2) full sets of manuals over to owner prior to conducting training of owner personnel.

4) Training:

a. Provide training in start-up, operation, and maintenance of equipment supplied using the services of a factory-certified representative of the manufacturer. Provide 2 training sessions of 2 hours minimum, each, on separate days.

b. Submit training plan for owner's approval. Training plan to include duration of training sessions, suggested class size/attendees, locations, lesson objectives, and outline of training topics.

5) Warranty

a. Provide 5–year extended warranty against defects in materials and workmanship. Warranty period shall begin after certified substantial completion. Extended warranty shall also include the automatic transfer switches.

6) Acceptable Manufacturers: Asco, Russ Electric

7) Definitions:

a. ATS: Automatic Transfer Switch

b. CTTS: Closed Transition Transfer Switch

c. BPS: Bypass Switch

8) Auto-transfer switch (ATS):

a. Mechanically held, electrically operated type

b. Designs utilizing components of molded-case circuit breakers, contactors, or parts thereof, which are not intended for continuous duty, repetitive switching, or transfer between two active power sources, are not acceptable.

c. Shall be rated to close on and withstand the available RMS symmetrical short circuit current at the CTTS/BPS terminals with the type of overcurrent protection shown on the plans.

d. Shall be closed transition type. Trip upstream breakers if switch fails to transfer leaving both sources in parallel.

e. Neutral Switch: Provide 100% switched neutral for 3–phase, 4–wire systems to insure there is sufficient line to ground current to clear upstream circuit breaker. A solid neutral terminal or overlapping neutral is not acceptable and shall not be provided.

f. Switching Arrangement: Double-throw type, incapable of pauses or intermediate position stops during normal functioning, unless otherwise required.

g. Manual Switch Operation: Under load, with door closed and with either or both sources energized. Transfer time is same as for electrical operation. Provide external operator to prevent injury to operating personnel.

h. Transfer switches shall be dual operator, double throw, closed transition, actuated by two electric motor operators or electric solenoids momentarily energized, and connected to the transfer mechanism by a simple over center type linkage.

i. The ATS/BPS shall be UL listed in accordance with UL 1008. Provide switch with the following items:

1) Voltage and frequency on both the normal and emergency sources (as noted below) shall be continuously monitored, with the following pickup, dropout, and trip setting capabilities (values shown as percentage of nominal unless otherwise specified):

Parameter	Sources	Dropout / Trip	Pickup / Reset
Undervoltage	N&E,3ϕ	70 to 98%	85 to 100%
Overvoltage	N&E,3ϕ	102 to 115%	2% below trip
Underfrequency	N&E	85 to 98%	90 to 100%
Over frequency	N&E	102 to 110%	2% below trip
Voltage unbalance	N&E	5 to 20%	1% below dropout

2) Source differential sensing shall be provided for the closed transition operating mode.

3) Closed transition transfer shall be accomplished with no power interruption and without altering or actively controlling standby generator set.

4) A three-position momentary-type test switch shall be provided for the test / automatic / reset modes.

5) Provide for a low-voltage engine start signal. The start signal shall prevent dry cranking of the engine by requiring the generator set to reach proper output and run for the duration of the cool down setting, regardless of whether the normal source restores before the load is transferred.

6) An in-phase monitor shall be provided. The monitor shall control transfer so that motor load inrush currents do not exceed normal starting currents and shall not require external control of power sources.

7) The controller shall provide an internal engine exerciser.

8) Two (2) Aux contacts rated 10A, 250 VAC to close when normal power fails.

9) Two (2) Aux contacts rated 10A, 250 VAC to open when normal power fails.

10) Two (2) Aux contacts rated 10A, 250 VAC on same shaft as main contacts (closed on normal).

11) Two (2) Aux contacts rated 10A, 250 VAC on same shaft as main contacts (closed on emergency).

9) Bypass/isolation Switch (BPS):

a. Manual type, arranged to select and connect either source of power directly to load, isolating transfer switch from load and from both power sources. Include the following features for each combined automatic transfer switch and bypass/isolation switch:
   1) Means to lock the bypass/isolation switch in the position.
   2) Draw out arrangement for transfer switch.
   3) Separate bypass and isolation handles shall be utilized to provide clear distinction between the functions.

b. Provide the following auxiliary contacts for the bypass switch:

   1) Two (2) aux contact on bypass switch closed in bypass normal position; contacts rated 10A, 250 VAC.
   2) Two (2) aux contact on bypass switch closed in bypass emergency position; contacts rated 10A, 250 VAC.
   3) Two (2) bypass aux contact closed when bypass switch is in auto position, rated 10A, 250 VAC.
   4) Two (2) isolation aux contact closed when isolation handle is in closed position, rated 10A, 250 VAC.

10) Generator ATS Start Control Wire Monitoring

a. Provide audible and visual notification of generator remote start circuit at generator control panel and remote annunciators. Fault condition shall automatically start generator. Install audible and visual notification at generator and each automatic transfer switch.

11) Enclosure

a. Adjustable and renewal parts and cable terminations shall be accessed from front and rear of enclosure only. Side access shall not be allowed.
b. Provide 4–inch crystal infrared view port positioned to view each power feeder and service conductor termination.

12) Metering and Monitoring

a. Provide flush mounted meter on front door of the transfer switch enclosure.
b. The following data shall be available on the display and Modbus registers of the Power Meter:
   1) Line-to-neutral voltages (VAN, VBN, and VCN)
   2) Line-to-neutral voltage average (VAVE)
   3) Line-to-line voltages (VAB, VBC, and VCA)
   4) Line-Line voltage average (VLAVE) ● Current on each phase (IA, IB, and IC)
   5) Current on the neutral conductor (IN)
   6) Average current (IAVE)
   7) Active power, KW per phase and total (WA,WB,WC, and WT)
   8) Apparent power, KVA per phase and total (VAA, VAB, VAC, and VAT)
   9) kWHours importing, exporting, and net (kWHIMP, kWHEXP, and kWHNET)
   10) kVARHours leading, lagging, and net (kVARHLEAD, kVARLAG, and kVARHNET)
   11) Power factor (PF)
   12) Frequency (Hz)
   13) Digital Input

13) Monitoring – Event

a. Date and time and reason for transfer normal to emergency.
b. Date and time and reason for transfer emergency to normal.
c. Date and time and reason for engine start.
d. Date and time engine stopped.
e. Date and time emergency source available.
f. Date and time emergency source not available.

14) Monitoring – Statistical

a. Total number of transfers.
b. Total number of transfers due to source failure.
c. Total number of days controller is energized.
d. Total number of hours both normal and emergency sources are available.

15) Provide load add and load shed control relay in optional standby transfer switches.

16) Furnish and install required appurtenances for communications to Caltech EMS.

17) Construction:

a. Switches shall be sized and have mechanically braced contacts to withstand momentary surge currents during transfer and retransfer.
b. Each switch shall be capable of manual operation by one person.

18) Installation:

a. The transfer switch shall have controls to auto-start the engine generators upon power failure and to automatically shut down the engine generator upon normal power return.

Section 26 50 00 – Lighting

26 51 00 Interior Lighting

1. Lighting Fixtures:

a. General:

1) Except where not possible or will not meet requirements in a specific area, all lighting shall be LED technology of the highest grade, and otherwise follow the other requirements of this section.
2) Interior lighting shall be 3500K with a field-selectable 4000K option.
3) Lighting fixtures shall have all parts and fittings necessary to completely and properly install the fixtures.
4) All fixtures shall be the standard product of fixture manufacturers unless otherwise shown, and shall be Underwriters Laboratories (UL) approved. Provide seismic support to all fixtures.
5) Lighting fixtures longer than 4 feet, including continuous-looking runs formed by abutting fixtures together, shall be avoided unless otherwise approved by Caltech PM.
4) All fixtures of one type shall be of one manufacturer and of identical finish and appearance.
7) All exit signs shall be LED based and include self-testing and diagnostic features. Self-luminous and tritium-based signs shall not be utilized. No exit signs that contain any tritium shall be used.
6) All undercounter task lights to be LED based.
9) Bug eye fixtures: Hubbell Dual Lite LZ series with Spectron (self-diagnostic option).

10) Refer to **Electrical Standard Lighting Specs List** for Caltech preferred lighting fixtures. Obtain approval from Caltech PM and Electrical Shop for any fixtures not included on the list.

b. Ballasts:

1) All fluorescent fixtures shall be furnished with ballasts with following characteristics:

a) Standard ballasts shall be electronic “programmed start” type.
b) Dimming ballasts shall have capabilities to control from 100% down to 5% of full light output.
c) High power factor magnetic ballasts shall be provided for all areas sensitive to high frequency electronic ballasts.
d) The ballast shall have lowest harmonic content and total harmonic distortion (not to exceed 15% on total harmonic and 10% on third harmonic content).
e) Provide ballasts with built-in line RFI suppression and have surge and transient protected to 6000 volts.
f) Ballasts for exterior fixtures shall be low temperature type for operating at +20º F.
g) 3– and 4–lamp ballasts are not acceptable.

h) Fixture-integral emergency battery packs shall include self-testing and diagnostic features. Avoid fixture-integral emergency battery packs unless specifically approved in writing by the Caltech Planning, Design & Construction project manager.

c. Lamps:

19) Provide high intensity discharge lamp ballasts with high power factor regulating type, conforming to applicable NEMA standards.
20) Provide high intensity discharge ballasts of the encapsulated type with lowest sound rating available.
21) All ballasts for HID fixtures shall be high power factor, low noise, and low EMF type ballasts.
22) Minimum starting temperature shall be –20º F.
23) Contractor to provide Caltech with 2% spare lamps (minimum of one) attic stock for each lamp type utilized on the project.

1) Fluorescent: no new fluorescent lighting shall be installed on campus.
2) HID:

a) Where possible all HID lamps shall be color corrected ceramic type.
b) Lamps should be 3500K with field-selectable 4000K option and highest available CRI. Where existing adjacent spaces utilize different color temperature, coordinate with Caltech PM, Electrical Shop and the Director of Planning, Engineering & Architecture on color selection.

8) Incandescent:

a) Use of incandescent lamps shall be limited to areas with special requirements, and only with the written approval of Caltech Planning, Design & Construction PM and Electrical Shop supervisor.
b) Use energy saving type halogen IR type for all applications where PAR lamps are required.
c) Use of low voltage lamps shall be limited to areas with special requirements, and only with the written approval of Caltech Planning, Design & Construction PM and Electrical Shop supervisor.

9) LED:

a) All lighting shall be of light emitting diode (LED) type unless approved by Caltech for specific applications.
b) LED lighting shall have the following minimum requirements

(1) General illumination LED lighting color temperature shall be coordinated with Planning, Design & Construction PM and architect for approval.
(2) Color rendering index shall be highest available, with a minimum of 80.
(3) Power factor ≥ 0.9.
(4) Total harmonic current distortion (THDi): ≤ 20%

c) All illuminated exit signs shall be furnished with green LED lamps.

d. Installation:

1) All fixtures shall be installed at locations that could be easily accessed by Facilities personnel for re-lamping or replacing ballasts or other parts.

2) Central inverter units shall be provided for emergency lighting requirements (described in this document) for projects where another source (generator) is not provided/available. Fixture integral emergency battery packs shall be avoided unless specific written approval is obtained from the Caltech Planning, Design & Construction project manager. Emergency lighting inverters shall be manufactured by Myers or Sure-Lites.

2. Lighting Control System:

a. Furnish and install a complete system for lighting controls as indicated on the drawings.

b. Where other than stand-alone typical light switches are used, Acuity Night light controls with Wi-Fi shall be used.

c. All components and devices (i.e. power supplies, relays, modules, etc.) shall be accurately shown on as-built drawings.

d. Lighting control wire shall be Cat 6 purple color.

e. nLight Eclypse: All new lighting control systems (new or upgrades) shall have an nLight Eclypse with Wi-Fi. Where an existing space is renovated, resulting in an update to the majority of a building's floorplan (i.e. >50%), an nLight Eclypse system will be installed and networked to the scoped renovated space as part of the completion of the lighting and lighting controls scope.

26 56 00 Exterior (Site) Lighting

1. General:

a. Consult Caltech project manager regarding information specific to site lighting on campus.

2. Area Lighting:

a. Design for the exterior light fixtures shall comply with applicable lighting industry standards such as dark sky initiative and BUG rating.

b. **Provide exterior LED lighting with 3000K CCT** and highest CRI available, CRI 80% at minimum. The 3000k standard is intended to provide a warm, comfortable nighttime environment, reduce short-wavelength (blue) light associated with sky glow, limit visual glare and light pollution, and support night sky preservation while maintaining appropriate safe visibility for the campus community.

c. Outdoor lighting poles should be the BEGA specific bronze; no other products will be accepted.
   1) Pole P/N: 14RHTS1
   2) Pole top luminary. This part number depends on the architect lighting pattern requirements.
      a. Symmetric wide beam: PN: 84403; 3000K
      b. Asymmetric: PN: 84401; 3000K

DIVISION 27 – COMMUNICATIONS

Section 27 20 00 – Voice and Data Communications

1. Caltech Voice and Data Network Specifications and CITNet Standards:

Introduction

This document attempts to provide the design requirements and guidelines for the planning and construction of telecommunications facilities at the California Institute of Technology (Caltech) in Pasadena, California. The scope of work includes the telecommunications inside plant (ISP), outside plant (OSP), and support facilities required by any construction on campus. This document is a design guide and not a project specifications document.

CITNet utilizes well known, established industry standards and best practices for structured cabling to provide the highest quality networks at Caltech. These standards are updated from time to time as newer standards become available (e.g., 10G, 100G, 800G, wireless networking technologies, etc.), technology improvements allow improved functionality (e.g., fiber connectors, Cat 6A, 7, 8, etc.), cost is driven down, or campus demand warrants. Note that these standards are subject to change without notice.

Consultation with Caltech IMSS is strongly encouraged prior to and during the design process for updates to technologies, industry standards, and Institute standards that evolved after the publication of this document.

Reference Documents and Standards

1. Caltech IMSS Construction Specifications, are available at http://networkspec.caltech.edu
2. All products, services, materials, documentation, and designs provided by the installer/contractor/designer shall meet the requirements of the following where applicable:
    a. National Electrical Manufacturer's Association (NEMA)
    b. American National Standards Institute (ANSI)
    c. Safety-related organizations, including
        i. National Fire Prevention Act (NFPA)
            1. National Electric Code 2019 (NEC)
        ii. Relevant State Electric and Fire Codes
        iii. Institute of Electrical and Electronic Engineers (IEEE)
        iv. Underwriters Laboratories (UL)
    d. Telecommunications Industry Alliance
        i. TIA–526–7A Fiber Optical Power Loss Measurements SM
        ii. TIA–526–14C Fiber Optical Power Loss Measurements MM
        iii. TIA–568.0–E Generic Telco Cabling Customer Premises
        iv. TIA–568.1–E Commercial Building Telecommunications Infrastructure Standard
        v. TIA–568.2–D Balanced Twisted Pair Cabling and Components
        vi. TIA–568.2–D–1 Balun Requirements for Category 8 Testing — Addendum to TIA–568.2–D
        vii. TIA–568.3–D Optical Fiber Cabling Components Standards
        viii. TIA–568.3–D–1 Optical Fiber Cabling and Components Standard — Addendum to TIA–568.2–D
        ix. TIA–568.4–D Broadband Coaxial Cabling and Components Standard
        x. TIA–569–E Telecom Pathways and Spaces
        xi. TIA–570–D Residential Telecommunications Infrastructure Standard
        xii. TIA–598–D Optical Fiber Cable Color Coding
        xiii. TIA–598–D–1 Optical Fiber Color Coding in Cable — Addendum 1, Additional Colors for Elements 13–16 — Addendum to TIA–598–D

xiv. TIA–598–D–2 Optical Fiber Cable Color Coding — Addendum 2, Jacket Color for OM5 Indoor Fiber Cables — Addendum to TIA–598–D
xv. TIA–606–C Administration Standard For Telecom Infrastructure
xvi. TIA–607–D Grounding and Bonding
xvii. TIA–758–B Customer Owned OSP
xviii. TIA–942–B Data Centers
xix. TSB–5069 Optical Fiber Channel Polarity — Duplex-Single and Dual Row Fiber

e. Building Industry Consulting Service International (BICSI) Publications:
i. Telecommunications Distribution Methods Manual (TDMM), 14th ed.
ii. Outside Plant Design Reference Manual (OSPDRM), 6th ed.
iii. Information Technology Systems Installation Methods Manual (ITSIMM), 7th ed.
iv. Telecommunications Project Management Manual (TPMM), 1st edition
v. ANSI/BICSI 006, Distributed Antenna System (DAS) Design and Implementation Best Practices
vi. ANSI/BICSI 008, Wireless Local Area Network (WLAN) Systems Design and Implementation Best Practices
vii. ANSI/BICSI 005, Electronic Safety and Security (ESS) System Design and Implementation Best Practices
viii. ANSI/BICSI 007, Information Communication Technology Design and Implementation Practices for Intelligent Buildings and Premises
ix. ANSI/BICSI 001, Information and Communication Technology Systems Design and Implementation Best Practices for Educational Institutions and Facilities

f. Audio/Video Standards and Publications:
i. InfoComm International, “ANSI/InfoComm 1M–2009 Audio Coverage Uniformity in Enclosed Listener Areas Standard.” (IMSS — Academic Media Technologies)
ii. InfoComm International, “ANSI/InfoComm 2M–2010 Standard Guide for Audiovisual Systems Design and Coordination Processes.” (IMSS — Academic Media Technologies)
iii. InfoComm International, “ANSI/InfoComm 3M–2011 Projected Image System Contrast Ratio Standard.” (IMSS — Academic Media Technologies)
iv. InfoComm International, “ANSI/InfoComm 4:2012 Audiovisual Systems Energy Management Standard.” (IMSS — Academic Media Technologies)
v. InfoComm International, “InfoComm F501.01:2015 Cable Labeling for Audiovisual Systems.” (IMSS — Academic Media Technologies)
vi. InfoComm International, “ANSI/INFOCOMM V202.01:2016 Display Image Size for 2D Content in Audiovisual Systems.” (IMSS — Academic Media Technologies)
vii. InfoComm International, “Dashboard for Controls Design Guide.” (IMSS — Academic Media Technologies)
viii. InfoComm International, “Basics of Audio and Visual Systems Design,” Revised Edition. (IMSS — Academic Media Technologies)
ix. InfoComm International, “AV Installation Handbook.” (IMSS — Academic Media Technologies)

g. Manufacturer’s recommendations and installation guidelines
h. All cabling shall comply with all appropriate requirements of NEC Articles 770 and 800 and shall comply with the state fire codes as interpreted by the State Fire Marshall’s department.

3. All publications referred to in this document shall be the latest edition thereof together with any amendments and/or addenda current ten days before the date fixed for return of bids.
4. Caltech IMSS is the owner of the campus structured cable plant and shall be consulted for additional information and clarifications pertaining to the design, implementation, and operation of the campus communications systems.

Definitions

1. ADF: Area Distribution Frame (see TS/TR Facilities section, below, for details and usage)
2. AHJ: Authority Having Jurisdiction
3. BDF: Building Distribution Frame (see TS/TR Facilities section for details and usage)

4. BICSI: Building Industry Consulting Services International, a professional and standards organization whose purpose is to support the advancement of information and communications technology.
5. EF: Entrance Facility (see TS/TR Facilities section for details and usage)
6. ER: Entrance Facility (see TS/TR Facilities section for details and usage)
7. Facilities: Caltech Facilities; information available at https://facilities.caltech.edu/
8. IDF: Intermediate Distribution Frame (see TS/TR Facilities section for details and usage)
9. IMSS: Information Management Systems and Services, Network and Support Services, the group responsible for voice and data network services at Caltech
10. ISP: Inside Plant
11. MAC: Moves/Adds/Changes, used in reference to Work Area Outlet network cabling.
12. OSP: Outside Plant
13. Permanent Link: The permanently installed portion of horizontal cabling, typically from a patch panel to the Work Area Outlet (excludes patch cables/patch cords)
14. RF: Radio Frequency
15. RFI: Radio Frequency Interference
16. TR: Telecommunications Room (see TS/TR Facilities section for details and usage)
17. WAP: Wireless Access Point
18. WAO: Work Area Outlet

Telecommunications Spaces

1. Telecommunication Spaces (TS): The term TS refers to space allocated within a building to provide a secure operating environment for telecommunications cabling, termination facilities, and network equipment. TSes shall be designed and provide services as outlined in TIA–569 and BICSI Telecommunications Distribution Methods Manual (TDMM), most recent editions. Building size, design, network requirements, and services provided to the building may permit one or more functions of a TS to be combined into one space. The primary functions housed in TSes are:
    a. Telecommunications Rooms (TR)
    b. Entrance Facilities (EF)
    c. Equipment Rooms (ER)
    d. Area Distribution Frame (ADF)
    e. Building Distribution Frame (BDF)
    f. Intermediate Distribution Frame (IDF)

TS/TR Facilities at Caltech

1. Types
    a. Entrance Facility (EF): A room that houses the terminations and grounding point of the OSP network service cables that enter or exit a building. It provides the joining of inter-building and intra-building services. The EF is typically located in the BDF rather than being a separate room. The EF is typically located on the same level as OSP services entering the building to minimize conduit installations from the exterior through the interior of the building. Historically, this function was combined with ADFs and BDFs at Caltech and referred to as the Main Distribution Frame (MDF) of a building.
    b. Equipment Room (ER): A room that houses telecommunications equipment.
    c. Area Distribution Frame (ADF): A multi-building serving facility. The ADF is a room within a building for telecommunications equipment that meets the voice, data, video, audio/video, radio, and wireless needs of its building and also serves other buildings in the designated area.
    ADFs are distinct from other TRs due to the nature and/or complexity of the equipment contained within. They are distribution points for the campus fiber and copper OSP cable plants. Design of these facilities must take into account the additional space required for fiber services from other buildings (e.g. rack space, cable routing, cable service loops, and so forth).
    The design of ADFs requires additional attention to meet fire/life/safety requirements they are expected to serve and are not generic enough in nature to be covered in this document.

   d. Building Distribution Frame (BDF): A building-serving facility. The BDF enables connection of the OSP services to the building and then distributes those services throughout the building to IDFs using riser cables. This function has traditionally been combined into the function of the EF/MDF.
   e. Intermediate Distribution Frame (IDF): Considered to be a floor-serving facility as opposed to a building-service facility. The IDF provides a connection point between riser cable from the BDF and the end user work area outlet (WAO) horizontal cabling. All new multi-story buildings shall have a minimum of one (1) IDF on each floor of the building. More than one (1) IDF per floor may be required in larger buildings where cable lengths of 85 meters (279 ft) are exceeded. Proposals for an IDF to serve multiple floors must be approved by Caltech IMSS prior to incorporation into any designs.
2. The TRs described above shall be designated for the exclusive use of the following telecommunications systems:
   a. Voice Systems
   b. Data network systems, including UPS systems (rack mount or room supporting)
   c. Wireless network systems
   d. Cellular telephone and in-building DAS systems
   e. Video surveillance systems
   f. Access control systems

TR Use Restrictions

1. No TR shall be used as a passageway to other rooms or facilities.
2. No TR shall be used as a passageway for other services, facilities, or utilities.
3. No TR shall be shared with other services or utilities.
4. TRs shall be designed and provisioned according to the requirements in TIA–569.

Design Requirements

Telecommunications spaces shall be:

1. Dedicated to the building's telecommunications function and related support facilities.
2. Not located on the roof of a building.
3. Not shared with other building services or equipment other than those required in direct support of the telecommunications equipment and services.
4. Not located near potential sources of electromagnetic interference (EMI) or radio frequency interference (RFI). Special care is required to design distributed antenna systems in such a manner as not to interfere with campus systems.
5. Located within the footprint of the floor above.
6. Located above water level.
7. Located as close as practical to the center of the area served.
8. Located to avoid shafts, elevators, electrical rooms, structural steel, stairwells, and other building features that will inhibit direct access to the TRs resulting in increased cable lengths to serve WAOs.
9. Located to facilitate cable lengths from TRs to WAOs not exceeding 85 meters.
10. Easily accessed from public hallways and permit the use of hand truck, pallet jack, or other conveyance for the transportation of equipment.
11. Accessed from the interior space of the building, not exterior doors.
12. Have easy access to distribution cable pathways.
13. Vertically aligned (stacked) within a multistory building to minimize conduit offsets through floors.
14. Horizontal pathways shall terminate in the TR located on the same floor as the area being served.
15. Meet local seismic requirements.
16. HVAC and other support equipment shall be located outside the TRs.
17. Electrical panels supporting TRs may be installed inside TRs provided there is adequate space and NEC required clearances do not interfere with the installation and operation of telecommunications equipment.
18. Fire suppression shall not be directly located over racks, cabinets, or telecommunications equipment. Fire suppression outlets (e.g. sprinkler heads) shall be protected from physical contact.
19. A TR numbering scheme is to be applied to all new and existing facilities.

20. A TR must be a rectangular room with no obstructions or protrusions (beams, columns, etc.) that decrease the usable square footage available in the room, including clearances required for installed equipment.
21. A TR shall be environmentally conditioned to support telecommunications electronics and the services provided by those electronics (e.g., Power over Ethernet). These systems shall be monitored by the campus for environmental status, operation, condition, and outage.
22. Constructed in such a manner to prohibit rodent and pest infiltration.

Telecommunication Room Assessments – Design and Pre-Construction Activities

Background:

The majority of Telecommunication Rooms (TRs) on campus were identified and outfitted from 1997 to 1999. Over 250 TRs exist across campus. Many of these rooms were designed and built to utilize existing spaces instead of constructing adequate, purpose built, industry best practices–based facilities. Additional compromises on design include (and are not limited to):

1. Inadequate cooling
2. Inadequate power
3. Improper access, clearances, and doorway sizes
4. Inadequate clearances between equipment and walls
5. Inadequate square footage to support future growth and newer technologies
6. Instead of serving the floor they are located on, serving multiple floors

All of these issues significantly impact our ability to provide services as data needs of the campus evolve. TRs that were constructed with limited room for growth are now at capacity and not able to support the additional cabling demands of the campus.

Method:

To ensure that network services can be provided following a renovation and new construction, the following steps must be followed:

1. A map of network ports and a complete port count must be provided to IMSS Network Services prior to final design and prior to setting the budget for a renovation.
    a. The campus design standards for network services shall be followed, including the two (2) ports per location requirement.
    b. Additional cables are required for phone service at the same WAO regardless of phone service type (analog, digital, VoIP...).
    c. WAO may contain more than two (2) data ports to meet end user needs or location needs.
    d. Wireless access point locations must be identified and included on the network map and port count. IMSS will assist in determining wireless access point locations. Vendor provided WAP locations must be approved in writing by IMSS prior to acceptance of a system design and prior to the project being sent out to bid.
2. Upon receipt of the network map and port count, IMSS will complete a network assessment to determine whether the existing TR can support the new renovation requirements.
    a. Every effort will be made to install services in the existing TR.
    b. In some renovations, a rearrangement of existing services may provide one-time relief from building a new TR. In these locations there will be a planned service outage of 1–2 days to relocate services, and the cost will be added to the project.
3. If it is determined that a new TR is required, IMSS will work with the project manager and building owner to identify appropriate locations, develop the scope-of-work, and estimate the total cost to build the TR as part of the renovation project. See also TR requirements section.

Room Construction Guidelines for TRs

1. Enclosing Walls
    a. TR walls shall extend to the structural ceiling above.

b. Fire rating of TR walls shall meet all requirements of the AHJ.
c. Penetrations of all fire rated TR walls shall be fire stopped.
d. Penetrations of all non-fire rated TR walls shall be blocked for acoustic and environmental conditioning.
e. TR walls shall be acoustically insulated when located adjacent to sound sensitive neighbors. Firestop materials may be used to seal conduits and through wall penetrations for uniformity of materials utilized on the jobsite.
f. Walls shall be finished and painted (no exposed drywall or jointing compounds).
g. Paint shall be light in color.

2. Ceiling
   a. Minimum height shall be 10 feet.
   b. There shall be no obstructions impeding the installation of telecommunications infrastructure and pathways between floor and ceiling.
   c. T-Grid or other “false ceilings” are not permitted; the structure of the floor above shall be visible.
   d. Ceiling shall be painted light in color.
3. Floor
   a. Sealed concrete
   b. VCT
   c. Raised floors are discouraged but may be approved by IMSS on a case-by-case basis.
4. Doors
   a. Single doors shall be 3 feet wide, 7 feet tall (or taller if architecturally required).
   b. Double doors shall be 6 feet wide, 7 feet tall (or taller if architecturally required).
   c. Doors shall be fire rated, as required.
   d. Doors shall be secured using the campus card access system (prox-card managed by Caltech Physical Security).
   e. Opens outwards.
   f. If opening inwards, door swing does not detract from the usable square footage of the room. Inward swinging doors must be approved by IMSS in writing.
5. Windows: TRs shall not have windows.
6. Water Infiltration
   a. Measures must be taken to prevent water intrusion. This includes ceiling, walls, and through the floor.
   b. No plumbing of any kind shall be routed through/within a TR. The only exception is the fire suppression systems installed to support the TR directly.
7. Fire Suppression Systems
   a. Sprinkler heads shall be installed per AHJ requirements.
   b. Sprinkler heads shall be caged.
   c. Sprinkler heads shall be of high-heat type.
   d. Sprinkler heads shall not be installed directly over telecommunications equipment.
   e. Sprinkler piping and heads shall not be located to interfere with the routing and support of telecommunications cabling and/or equipment.
   f. Dry action systems or chemical systems supporting TRs shall be installed outside TRs.
8. Wall Plywood Sheeting
   a. Plywood sheeting shall be installed in sufficient quantities to support the services attached to them.
   b. Plywood shall be fire rated and installed so the fire rating is visible for inspection.
   c. At no time shall walls be covered completely with plywood, only to adequately support wall mounted systems.
9. Electrical Outlets
   a. Electrical outlets shall be identified and labeled by source power.
   b. Generator/UPS outlets shall be visibly differentiated from unprotected power sources.
   c. Dedicated electrical outlets/circuits shall be installed to support telecommunications electronics. These outlets shall be specified per project and per room.
   d. Both emergency power and unprotected power shall be provided to support installed equipment.
   e. Convenience outlets shall be installed on walls per local code. Convenience outlets shall not be used to operate telecommunications electronics.

f. Outlets shall be installed in such a manner as to not create tripping hazards between outlets and equipment served.

10. Lighting
    a. Lighting shall be installed in such a manner to provide ample light to the front and rear of all workspaces.
    b. Lighting shall not utilize occupancy sensors.
    c. Lighting may utilize timers and allow occupants to manually override timers for the installation and maintenance of equipment.
    d. Lighting shall be installed in such a manner that permits maintenance/replacement of fixtures and lamps (and the required clearances for such work) without requiring the removal of racks, cable support systems, or other installed equipment.
    e. Lighting shall be ceiling mounted, wall mounted, or a combination of both.
    f. Lighting installations shall meet seismic requirements of AHJ.

Room Sizing Guidelines

1. Room sizing is project specific. Consult with IMSS and Facilities Planning, Design & Construction for requirements.

Room Layout (General Notes)

1. Lighting shall not receive power from the same electrical distribution panel as the telecommunications equipment in the TR.
2. MDF requires the installation of 4 post racks with vertical cable management in addition to 19–inch 2 post racks.
3. 4 post racks may support larger equipment, fiber optic enclosures for entry services, and fiber optic enclosures for in-building services.
4. 4 post racks shall be assembled to permit the installation of equipment no less than 17.75 inches in width.
5. 2 post racks shall be assembled to permit the installation of equipment no less than 17.75 inches in width.
6. Fiber shall be terminated in 4RU enclosures and be “flat front.”
7. Copper shall be terminated in 1RU, 48 port, angled patch panels specific to application.
8. Equipment racks shall be 7 feet tall, unless otherwise specified.
9. Vertical cable management (VCM) shall be used between all racks, cabinets, and enclosures. VCM shall be sized sufficiently to support connected racks and a cable density of 600 cables per rack.
10. Vertical cable management (VCM) for 4 post racks is required for open frame racks and can be omitted from scope if the 4 post rack cabinets possess in-cabinet vertical cable management.
11. Racks shall be installed in such a manner to permit a human to work behind a rack of equipment to install cable and support installed telecommunications equipment. Consult IMSS BIM for additional details.
12. Racks shall be installed in such a manner to permit the maintenance of installed telecommunications equipment, including the installation/removal/replacement of components without the removal of the telecommunications equipment. Allow for the removal of full-length power supplies, fans, and other field replaceable items.
13. Racks shall support commodity network services and specialty network services.
14. HVAC support is required.

Room Environmental Requirements

1. HVAC shall be dedicated for each TR and independent of comfort cooling.
2. HVAC shall operate 24/7/365 and be centrally monitored.
3. HVAC filters are to be high efficiency and high filtration.
4. HVAC systems shall be installed external to the TRs to minimize exposure to water piping.
5. In instances where HVAC systems installed are of the chilled water or split system type, plumbing shall be routed in such a manner to completely avoid structured cable plant and telecommunications electronics.
6. Temperature in TRs shall be between 68º Fahrenheit and 72º Fahrenheit.
7. Humidity shall be non-condensing.
8. Temperature and humidity controls shall comply with ASHRAE Technical Committee 9.9 and meet Caltech IMSS specific requirements for telecommunications equipment installed.
9. Air exchange shall occur no less than once per hour.

10. Rooms shall be positively pressurized.
11. When TRs are UPS/Generator backed, HVAC systems shall also be backed by emergency power.
12. Condensate from HVAC equipment shall be routed away from telecommunications equipment and disposed of in accordance with AHJ.

Room Electrical Requirements

1. Sub-panels shall provide power to all TRs. Panels shall be 208Y/120V 3 phase, 4 wire.
2. Electrical outlets providing power to telecommunications equipment shall be dedicated circuits.
3. GFCI receptacles shall not be used to support TR applications unless required by AHJ.
4. Two electrical outlets providing wall sourced convenience power may share a single circuit. Convenience outlets shall be installed per code with no less than 1 outlet per wall.
5. Sub-panels should be installed inside TRs near the entrance door. Sub-panels shall include a lock.
6. Where emergency power and unprotected power exist in the same TR, panels shall be installed next to one another and clearly identified as to source. Outlets for each type of power shall be visually differentiated from one another.
7. Electrical panels shall contain detailed panel schedules for all circuits.
8. Electrical estimates per TR will be provided by Caltech per job. These estimates will be provided after the number of network cables and types of fielded equipment (WAPs, phones, and other PoE devices) a TR is to support is provided as this dictates the electronics (and subsequent electrical and cooling requirements) to be installed.
9. NEMA 5–20R outlets shall be used for 120VAC and fed from a dedicated circuit.
10. NEMA L6–20R and L6–30R outlets shall be used for 208VAC.
11. NEMA L6-20R outlets shall use upsized wire to permit the upgrade to L6–30R receptacles.
12. Other outlet configurations may be required based on equipment requirements per TR.
13. Electrical outlets shall be installed on ladder racking at the top of racks in such a manner to provide electrical power per rack and not interfere with the structured cable plant or installed equipment.
14. Electrical may be provided by drop cables from the ceiling, if practical.
15. Rackmount PDUs shall be installed to provide in-rack power distribution. Consult with IMSS as to type of PDU to be used on project.
16. Zero-RU PDUs shall be used where possible with 4 post racks and cabinets. 4 post racks and cabinets need to be sized accordingly to support this.
17. Zero-RU PDUs shall be color coded to reflect “A” side and “B” side power.
18. It is recommended a minimum receptacle configuration consists of:
    a. MDF
        i. Qty 4, NEMA L6–20R.
        ii. Qty 4, NEMA 5–20R duplex
        iii. Subject to adjustment per project, approved by IMSS in writing.
    b. IDF
        i. Qty 2, NEMA L6–20R.
        ii. Qty 4, NEMA 5–20R duplex
        iii. Subject to adjustment per project, approved by IMSS in writing.

Telecommunications Ground and Bonding

1. Telecommunications grounding and bonding systems shall be designed and installed to support the telecommunications infrastructure. The requirements of this system are specified in TIA–607.

Fire Safety and Protection

1. Portable fire extinguishers shall be installed within 50 feet of the room and publicly accessible.
2. Portable fire extinguishers installed in the room shall be installed next to the entry door.
3. Fire protection systems installed in TRs shall be done in such a manner as to not interfere with structure cable, cable pathways, or telecommunications electronics.
4. Fire protection systems installed in TRs shall be done in such a manner to permit maintenance after the installation of structure cable, cable pathways, and telecommunications electronics.

5. Spray foam sealants are not allowed for use with telecommunications cabling systems.
6. Pre-action systems, dry standby systems, gas or chemical systems shall be designed with the input of IMSS and Facilities.
7. Fire protection systems installed shall not “run through” or interfere with structured cable plant pathways and systems.

Telecommunications OSP Pathway

1. A dedicated, protected pathway shall be constructed from outside the building/construction area to the building’s entrance facility. This protected pathway shall provide access to other campus telecommunications connection points using rigid conduit, sleeves, conduits encased in concrete, EMT, cable tray, duct systems, or similar cable transit systems as approved by IMSS Network Services.
2. 4–inch rigid conduit shall be used to provide services to the building.
3. A minimum of four (4) conduits shall connect the entrance facility (typically the MDF) to external services.
4. In instances where external services are not directly connected to the EF/MDF (e.g. pathways traverse intermediate rooms or pathways), conduits, sleeves, tray, and other pathway materials/systems shall be used to provide a continuous pathway from the building EF to communications sources outside the building, in the required quantity and sizes, along the entire pathway.
5. The conduits shall be sufficient in quantity and size to support two (2) armored fiber optic cables of no less than 288 strands each and an armored telephone cable of no less than 200 pairs and no greater than 800 pairs. Support for other services may be required through OSP pathways and sized to accommodate.
6. For conduits with an internal diameter greater than 2 inches, the inside bend of a radius shall be no less than 10 times the diameter of the conduit.
7. Below grade conduits shall be encased in concrete.
8. Conduits shall be installed and terminate in such a manner to protect cables being pulled through them.
9. Conduits shall contain pull string.
10. Communications tray entering a building shall utilize fire stop “pillows” to permit re-entry of the tray.
11. Manholes or vaults shall permit the use of service loops and keep the cable off the bottom of the vault. Manholes or vaults shall be designed to prohibit pooling or standing water.
12. Dual OSP entrances from different OSP point(s) of connection shall be utilized on all projects.
13. Dual OSP paths shall be routed diversely from each other and minimize common pathing.
14. OSP shall be designed per BICSI, OSPDRM.
15. A pathway to the roof is required for NTP/Fire/Life/Safety/Repeater/DAS/DBS and similar systems. No less than (1) 4–inch conduit shall be installed to support network services. Additional conduits and pathways shall be specified per project to support services such as NTP, DAS, cell phone relay, and similar services. Conduit size, quantity, and pathways will be specified per project/building.
16. Pathways for roof-based services (e.g. solar, HVAC equipment) shall be as direct as possible and utilize pathways on the floor below.
17. Pathways for roof-based services (e.g. solar, HVAC equipment) shall take paths that do not transit TRs.
18. OSP paths that are at 40% fill shall not be used for additional cables; new pathways shall be installed. Additional conduits shall be 4 inches or greater.
19. All conduits must utilize protective bushings.
20. Pathways shall not be direct burial; pathways shall facilitate replacement of cables.
21. Newly established pathways shall be built to utilizing a minimum of 4 inches of pathing to support replacement of the installed OSP cable plant.

Telecommunications ISP Pathways

1. Pathways
    a. Coordination of pathways is required. The design of the riser conduit system must take into account all communications systems to be vertically and horizontally integrated in the building. Design of these pathways must account for all interconnecting fiber and copper systems in the building and be represented on one all-encompassing telecommunications construction document.

b. Telecommunications pathways are for the exclusive use of data network and voice structured cabling systems. Consult with IMSS for additional details.
c. All conduits must utilize protective bushings.

2. Interior Pathways
   a. Cable tray may be solid bottom to meet site conditions; Caltech Facilities Planning, Design & Construction and IMSS will advise.
   b. Cable tray may be basket to meet site conditions; Caltech Facilities Planning, Design & Construction and IMSS will advise.
   c. Feeder cable tray size shall be a minimum of 12 inches in width existing from TR.
   d. All tray installations shall support a maximum fill ratio of 40%.
   e. Tray top and sides shall be unobstructed by other trades to support installation of cable, moves, adds, and changes.
   f. Tray top shall have unobstructed access and top side vertical minimum clearance of 8 inches to permit installation of cable.
   g. Tray shall be used for horizontal structured copper cable plant. Armored cables (fiber or otherwise) shall not occupy the same tray. Third party cable shall not be installed in tray dedicated to the structured copper cable plant; alternate pathways shall be utilized. Alternate pathways may run parallel to structured copper cable plant tray and be installed in such a manner not to interfere with or prevent access to the structured cable plant pathways.
   h. Reduction in cable tray size may be done when field conditions permit and with the explicit approval of Caltech Facilities Planning, Design & Construction and IMSS. Fill ratios shall be observed.
   i. Cable tray shall meet local seismic zone requirements.
   j. Cable tray layout shall be reviewed and approved by the Institute representative.
   k. Cable pathways must provide capacity for future use and replacement of the existing cable plant.
3. Riser Pathways
   a. Riser pathways connect TRs on different floors.
   b. Between-floor pathways shall consist of 4–inch conduits with a minimum of three (3) unique conduits from the MDF to each IDF.
   c. Between-floor pathways for stacked TRs may utilize through-floor sleeves with cable support as long as those sleeves are adjacent to a wall that exists in the same vertical position on both floors.
   d. Riser conduits for antenna systems, BMS, DAS, GPS/NTP, or DBS may transit through TRs but are not permitted to share conduits with the telecommunications structured cable plants.
   e. Riser conduits shall not be used for/as electrical pathways.
   f. Spare conduits for future use are required.
   g. Riser pathways shall be fire stopped in accordance with all standards and codes.
   h. Riser pathways shall be interrupted as required to support cable blocking and cable supports to meet multi-floor riser cable installations per BICSI and AHJ requirements.
4. Primary Horizontal Cabling Pathways
   a. Primary horizontal cable pathways are the major pathways that transport the structured cable plant to the WAO locations. This can be done with cable tray and/or conduit.
   b. Tray shall be sufficiently sized to support WAO cabling at a 40% cable fill ratio to permit MACs or shell build-out.
   c. Conduits and tray shall not exceed 40% fill. Visual fill may require additional conduits be utilized before the calculated fill is reached.
   d. Primary horizontal cabling pathways should utilize building pathways for other utilities and/or movement of people through the building.
   e. These pathways shall be installed in a manner to permit unobstructed access by or to other utilities.
   f. These pathways shall be, as much as practical, routed outside of offices, labs, or otherwise private spaces to minimize impact on building occupants when re-entry to these pathways is required.
   g. Cable pathways must provide capacity for future use and replacement of the existing cable plant.
   h. Visible pathways shall be cable tray or basket tray; J-Hooks shall not be used where pathways are visible from the floor (e.g. open ceiling designs).
5. Secondary Horizontal Cable Pathways

a. Secondary horizontal cable pathways provide a path from the primary pathway to the WAO.
b. Conduits shall be installed within 3 feet of the primary horizontal pathway.
c. Wall boxes for WAO jacks shall consist of a single- or multi-gang wall box with mud ring. Size of the box is determined by the number of jacks served by this outlet.
d. A maximum of 6 jacks may be fed from a single-gang wall box.
e. Wall box shall be connected to conduit leading to the primary horizontal pathway.
f. Wall box and conduit shall utilize bushing to protect cabling.
g. Wall box shall be deep enough to support cable bend radius.
h. Conduit for a single-gang wall box shall be sized to support 6 cables at a 40% fill ratio.
i. Larger wall boxes shall have their conduits sized to support the maximum number of cables capable of being pulled to that location and maintain a maximum fill ratio of 40%.
j. Modular furniture pathways will require special consideration and project approval.
k. Wall mounted raceway will require special consideration and project approval.
l. J-Hooks shall be installed in accordance with manufacturer's specifications.
m. Visible pathways shall be cable tray or basket tray; J-hooks shall not be used where pathways are visible from the floor (e.g. open ceiling designs).

6. Pathway Fill
    a. Conduit and tray installation and fill ratios shall be in compliance with BICSI TDMM.
    b. J-Hook fill and loading shall be in accordance with manufacturer specifications and meet BICSI TDMM requirements.

Structured Cabling Systems

1. General
    a. Structured cabling systems consist of all physical facilities, pathways, and cable systems (end-to-end) used to deliver data and/or voice services between two endpoints, excluding electronics.
    b. All cable and terminations shall be labeled in accordance with Caltech standards.
    c. Cabling shall be properly supported and not in contact with other trades, including sharp edges and/or threaded rod.
    d. Cabling shall be installed point-to-point without splices, unless otherwise specified.
    e. Cables shall be plenum rated.
2. OSP Fiber
    a. Cable shall be reel tested, results submitted, results reviewed by IMSS and approved in writing prior to installation.
    b. Cable pathways shall be approved in writing prior to use/installation of cable(s).
    c. Installed cable(s) shall be inspected for pathway placement and cable routing prior to termination.
    d. Cable plant to be Corning Certified and have a minimum of a 25–year, end-to-end warranty.
    e. Cable shall be armored.
    f. Cable shall be fusion spliced to LC connectors unless otherwise specified.
    g. Cable shall consist of at least 144 strands.
    h. Cable shall be single mode "Ultra Low Loss SMF–28" and support 1310nm, 1550nm, and 1625nm.
    i. Cable shall support DWDM and CWDM applications.
    j. Cable shall support speeds no less than 1.6Tbps.
    k. Cable shall be fully terminated (no unterminated strands), tested and certified prior to Institute acceptance.
    l. Fiber enclosures shall be installed at top of rack.
    m. Air Blown Fiber (ABF) systems may be proposed for consideration.
    n. Multimode entry fiber is not utilized at Caltech.
3. ISP Fiber
    a. Cable plant to be Corning Certified and have a minimum of a 25–year, end-to-end warranty.
    b. Cables shall be armored unless alternate(s) are approved by Caltech IMSS in writing.
    c. Cable shall be fusion spliced to LC connectors unless otherwise specified.
    d. Cable shall consist of no less than 48 strands and subject to higher strand counts as required by the project.
    e. Cable shall be fully terminated (no unterminated strands), tested, and certified prior to Institute acceptance.

f. Single Mode ISP Fiber
    i. Cable shall be single mode and support 1310nm, 1550nm, and 1625nm.
    ii. Cable shall support DWDM and CWDM applications.
    iii. Cable shall support speeds in excess of 1.6Tbps.
    iv. Cable shall be single mode “Ultra Low Loss SMF–28" and support 1310nm, 1550nm, and 1625nm.
g. Multimode ISP Fiber
    i. Multimode ISP fiber is no longer utilized at Caltech.

4. OSP Copper — Voice Services
    a. OSP copper solutions shall be a Pan-Gen certified solution and provide a 25–year, end-to-end Panduit warranty.
    b. Campus connection point shall be Dabney Hall unless otherwise agreed to in writing by Caltech IMSS.
    c. Cable shall be fully terminated and tested.
    d. Cable shall be armored.
    e. Cable shall be plenum rated indoor/outdoor.
5. OSP Copper — Data Services
    a. OSP copper solutions shall be a Pan-Gen certified solution and provide a 25–year, end-to-end Panduit warranty.
    b. Cable color other than yellow may be accepted.
    c. Cable shall meet all requirements of OSP copper cable.
    d. OSP copper data cable is typically used to provide WAO locations outside the footprint of the building, not provide entry services.
    e. Examples of OSP copper data cable include, but are not limited to:
        i. Exterior wireless access points (WAPs)
        ii. Video cameras.
        iii. Exterior work area outlets (WAOs).
6. ISP Copper — Voice Services — Riser
    a. ISP copper solutions shall be a Pan-Gen certified solution and provide a 25–year, end-to-end Panduit warranty.
    b. Shall connect MDF TR with IDFs utilizing a point-to-point cable (no splices, no mid-span access, no daisy-chain).
    c. Shall be of adequate pair count to support voice services fed from the IDF.
    d. Shall be plenum rated.
    e. Shall terminate at top of rack, below fiber terminations, above horizontal structured cable plant patch panels.
7. ISP Copper — Voice Services — Horizontal
    a. General
        i. ISP copper solutions shall be a Pan-Gen certified solution and provide a 25–year, end-to-end Panduit warranty.
        ii. There is no differentiation between cable installed for horizontal voice services and horizontal data services. Consult ISP Copper — Data Services — Horizontal for more information.
        iii. Cables shall be the same color as detailed in Division 270000 – Communications: Structured Cabling Systems: ISP Copper — Data Services — Horizontal (WAOs) (below)
        iv. Jacks shall be the same color as detailed in Division 270000 – Communications: Structured Cabling Systems: ISP Copper — Data Services — Horizontal (WAOs) (below)
        v. Terminations shall be T568B.
    b. Offices
        i. Offices shall have a minimum of one (1) phone cable per desk/seat.
    c. Lab
        i. Labs shall have a minimum of one (1) phone cable per work area.
        ii. Caltech Safety, occupant, or Facilities may require more than one (1) phone per work area.
        iii. Phone should be located near entrance to lab.
    d. Cubicles
        i. Cubicles for staff shall have a minimum of one (1) phone cable per work area/desk/chair.

ii. Cubicles for research shall have a minimum of one (1) phone cable per work area and may be shared amongst cubicles, at the occupant's discretion.
iii. Caltech Safety, occupant, or Facilities may require more than one (1) phone per work area.
iv. Shared phones should be located near entrance to work area.
v. Shared phones should be easily located within the work area.

e. Elevators
i. Elevator phones shall be served from the elevator mechanical room.
ii. Elevator phones shall be programmed to dial Caltech Security when "off-hook."

f. Common Areas, Building Entrances, and Hallways.
i. Architects shall plan for shared telephone resources in common areas to facilitate guests contacting building occupants or Caltech Security.

g. Mechanical/Electrical Spaces
i. Mechanical spaces shall have a minimum of one (1) phone.
ii. Caltech Safety, occupant, or Facilities may require more than one (1) phone per work area.
iii. Phone should be located near entrance to space and easy to locate.

h. Emergency Telephone
i. Emergency phones shall be programmed to dial Caltech Security when "off-hook."
ii. Protected pathways shall be utilized to provide cable to emergency phones.
iii. Consult with Caltech IMSS for emergency telephone system requirements and specific hardware supported by Caltech.

i. Wall Phones
i. Wall phones shall utilize faceplate design to support wall phone.
ii. Wall phone shall utilize 1 cable unless otherwise specified by the project.

j. Dorm Rooms/Residence Rooms
i. Dorm rooms shall have 1 phone per room.
ii. Phone jack may be installed in WAO with data ports.
iii. Where dorm room/residence room is a suite, 1 phone per suite is required, typically installed in the common room.

8. ISP Copper – Data Services (Riser)
a. Not typically in use at Caltech.
b. May be installed when required by specific use-cases.
c. Will meet ISP Copper — Data Services — Horizontal cable system requirements.

9. ISP Copper — Data Services — Horizontal (WAOs)
a. General
i. ISP copper solutions shall be a Pan-Gen certified solution and provide a 25–year, end-to-end Panduit warranty.
ii. Cable shall be Category 6A or better to WAO.
iii. Cable shall be plenum rated.
iv. Cable shall be yellow in color.
v. Cables shall not be spliced.
vi. Cables shall not be more than 85 meters in length.
vii. Phone and data may share a WAO faceplate.
1. Data cable(s) is/are installed in the faceplate first.
2. Voice cable(s) is/are installed in the last sequential port in the faceplate.
3. Jack positions in a faceplate are not "skipped" between data and voice cable positions.
4. Jacks are terminated at patch panel and at WAO in sequential order.
viii. All ports are "live."
ix. A minimum of two data cables are installed per WAO unless explicitly specified.

b. Faceplates
i. Duplex (single gang), quad (double gang) are supported.
ii. Label at top of faceplate designates Building-TR-Patch Panel (010–02–03). Leading zeroes required.
iii. Label at bottom contains contact information for support.

iv. Refer to IMSS Construction Specification 27 05 53 for labeling specifics (http://networkspec.caltech.edu/.
v. Faceplates shall contain sequentially numbered jacks from the same patch panel from the TR. Faceplates with jacks from multiple patch panels will be rejected.
vi. Faceplates to be installed 18 inches above finished floor (AFF) unless otherwise noted.
vii. Faceplate jack provisioning will have data jacks first followed by voice jacks.
viii. Jacks shall all be the same color, regardless of function (e.g., voice and data jacks and cables are treated the same).
ix. Jacks shall be individually numbered utilizing wrap-around labels specifically design for this purpose.

c. Offices
   i. A minimum of 2 data cables and 1 voice cable per office desk location/chair.
   ii. WAO shall be as close as practical to desk location.
   iii. WAO shall not be obstructed by furniture legs, furniture panels, or other features.
   iv. Additional WAO locations in the same office may provide 2 data cables if phone is not required at the additional locations.
   v. WAO placement shall support furniture layout and prohibit end user cable routing (e.g. patch cords) that results in trip hazard(s).
d. Open Office
   i. Open office cabling systems are not utilized at this time.
e. Lab
   i. A minimum of 2 data cables per desk/bench.
   ii. A minimum of 2 data cables per WAO not located at a desk/bench/work area.
   iii. Wall phone may be utilized to meet voice requirements.
f. Dorm Rooms/Residence Hall Rooms
   i. A minimum of 1 data cable per occupant per room (1 port per pillow).
   ii. Phone service may share WAO.
g. Cubicles
   i. A minimum of 2 data cables per desk/workspace/location.
   ii. Wall phone may be utilized to meet voice requirements.
   iii. Project must consult with Facilities and IMSS on the placement of WAO jacks on a wall/column or run through the modular furniture.
h. Elevators
   i. Elevator data requirements vary based on installation.
   ii. Data to elevators shall be provided by WAO installed in the elevator mechanical room.
   iii. A minimum of 2 data cables per WAO.
   iv. Voice cable(s) shall be installed in the same WAO supporting elevator data services.
i. Common Areas, Building Entrances and Hallways.
   i. Provisions for data cables in public spaces is highly recommended.
   ii. A minimum of 2 data cables per WAO.
j. Mechanical/Electrical Spaces
   i. A minimum of 2 data cables per WAO.
   ii. A minimum of 1 WAO per mechanical space for convenience/service use.
k. Card Access/Entry Systems
   i. A minimum of 2 data cables per WAO.
l. Video Surveillance
   i. Consult with Caltech Campus Physical Security http://security.caltech.edu/ as their use-case may have changed from the time of this writing.
   ii. Data for DVRs, if utilized, require a minimum of 2 data cables per WAO
   iii. Data for DVRs, if utilized, shall be installed in a patch panel located at the top of the rack the DVR(s) are installed at.
   iv. Data for camera locations require a minimum of 1 data cable per camera location.
   v. Locations where cameras require more than 1 data cable (as a hardware requirement to support the camera), shall be adjusted in count with additional cables to support fielded devices.

vi. Cables and jacks shall be integrated into the horizontal structured cable plant and not designed as a stand-alone system. Jacks shall not be terminated on a patch panel specific for camera use.

m. Building Management Systems
   i. A minimum of 2 data cables per WAO.
n. Specialty equipment (e.g., time clocks, calendars, networked monitors, and displays)
   i. A minimum of 1 data cables per WAO and increased as required to support fielded device.
o. AV Integration
   i. A minimum of 2 data cables per WAO.
p. High Density Computing Environments
   i. These are specialized areas with unique requirements. These areas need to be addressed on a case-by-case basis and are out of the scope of this document.

Wireless Networking

1. This section pertains to wireless networking per IEEE 802.11 wireless networking standards. Other wireless networks (e.g. DAS) have different design requirements and shall be designed specific to a site with input from IMSS and Facilities.
2. Wireless networking shall not be a replacement for a structured cable plant. Wireless is a complimentary telecommunications infrastructure that provides similar services but is not interchangeable with a dedicated copper or fiber cable plant.
3. One (1) cable shall be pulled to each wireless access point (WAP).
4. Cables shall be terminated to a faceplate or biscuit (WAO).
5. Patch cable(s) shall be used to connect WAPs to WAO.
6. Cables shall meet Division 27: Structured Cabling Systems: ISP Copper – Data Services – Horizontal (WAO) requirements, above.
7. Cables and jacks shall be integrated into the horizontal structured cable plant and not designed as a stand-alone system. Jacks and cables shall not be terminated on a patch panel specific for WAP use.
8. WAPs shall be ceiling mounted unless otherwise specified by IMSS to meet specific use-cases.
9. WAP mount kits are typically required and are to match installation location.
10. WAPs may be installed inside protective enclosures. Enclosures are to be of the type specifically for WAP installations and do not impede RF.
11. WAP enclosures shall be approved by IMSS in writing prior to bid acceptance, purchase, and/or installation.
12. WAPs are to be installed in accessible areas to facilitate maintenance, upgrade, and/or replacement.
13. WAPs placement shall be optimized for providing maximum coverage for areas served.
    a. WAPs shall not be obstructed by infrastructure or treatments.
    b. WAPs shall be installed away from RFI emitting devices.
    c. WAPs shall be installed away from other RF generating sources.
    d. Caltech wireless networking infrastructure shall take precedence in placement and operation over other wireless networks (e.g. BMS, Lighting control, A/V).
14. Exterior installation of WAPs may require specialized WAPs. Consult with IMSS for the models of exterior WAPs supported.
15. Wireless network designs shall be high density in nature to meet performance requirements at Caltech. (5 GHz attenuation is different than 2.4 GHz attenuation in various construction materials).
16. Wireless network designs shall support the following standards:
    a. Wi-Fi 5
    b. Wi-Fi 6
    c. Wi-Fi 6E
    d. Wi-Fi 7
    e. Wi-Fi 8
    f. Consult with IMSS Network Services for other wireless standards supported after the publication date of this document.

17. Wireless network design shall provide coverage throughout a building, including mechanical spaces within and supporting the building.
18. Wi-Fi and network health and monitoring sensors are required per TR and per floor. Consult with IMSS Network Services for exact quantity and placement.
19. Wi-Fi systems shall be designed to meet an RSSI value no less than –63dBm.
20. Wireless network design subject to final approval by IMSS prior to project incorporation.

Patch Cords

Patch cords used in the closets are color coded by function. The colors are:

1. Data (copper): yellow
2. Voice (copper): white
3. Data (single mode fiber): yellow
4. Data (bend insensitive single mode fiber): yellow/blue
5. Data (multi-mode fiber — 62.5/125µm): orange
6. Data (multi-mode laser optimized fiber — 50/125µm OM3/4): teal/aqua
7. Data (multi-mode laser optimized fiber — 50/125µm OM5): lime
8. Data (copper, crossover): red
9. Data (copper, serial — not network): green

Commissioning

1. Building Commissioning
    a. Commissioning requires operational network services connected to campus resources. A list of those services and locations for those services is required prior to project bid. Timeline information is required after the award of the project.
    b. Commissioning may occur prior to the completion of the network installation in the building. Provisions for temporary network services must be incorporated into the project. This includes, but is not limited to:
        i. Temporary OSP fiber/copper cabling to the building.
        ii. Temporary riser fiber/copper in the building.
        iii. Temporary horizontal fiber/copper in the building.
        iv. Temporary network electronics.
    c. Commissioning may require voice services. A list of those services and locations is required prior to project bid. Timeline information is required after the award of the project.
2. Telecommunications Systems Commissioning
    a. Network services will be installed after all construction activities in TRs are complete.
    b. Network services will be installed after all supporting systems for TRs are complete and operational.
    c. Network services will be installed after “IMSS Acceptance Punch List for Construction Projects” requirements are met.

Drawings and Construction Documents

Drawing set for telecom shall include all data jack locations for telecommunications and all other data requirements for other trades related to the project. This is done for coordination with other design requirements on the project. Other trades include, but are not limited to:

- BMS
- Audio/Video
- Video surveillance
- Card access systems
- Electrical metering systems
- Lighting control systems
- Environmental control systems

Caltech Voice and Data Port Symbol Legend

	Triangle, Half Shaded Default: (2) Data and (1) Voice, 18" AFF typical Option: Number on left of symbol specifies total cable count to faceplate. 6 cables would result in 5 data and 1 voice in one faceplate. Option: Number above symbol specifies faceplate location above finished floor (AFF). Measurement is taken from AFF to bottom of receptacle box.
	Triangle, Fully Shaded Default: (2) Data, 18" AFF typical Option: Number on left of symbol specifies total cable count to faceplate. Option: Number above symbol specifies faceplate location above finished floor (AFF). Measurement is taken from AFF to bottom of receptacle box.
	Triangle, Half Shaded, Circled Default: (2) Data and (1) Voice, Ceiling Mounted Option: Number on left of symbol specifies total cable count to faceplate. Option: Solid symbol indicating (2) Data only . May be modified to specify an alternate total quantity.
	Triangle, Half Shaded, Square Box Enclosing Default: (2) Data and (1) Voice, Floor Monument Option: Number on left of symbol specifies total cable count to faceplate. Option: Solid symbol indicating (2) Data only. May may be modified to specify an alternate total quantity.
	Triangle, Solid, Annotated Default: _____(1) Data (typical). Service may require more cables, service and application dependent. Supports specialty service. Letter Code located on right of symbol specifies function and/or service. Option: Number on left of symbol specifies total cable count to faceplate/WAO. Option: Modify to indicate floor or ceiling installation. Option: Modified to indicate height AFF. Letter Code: Required (List shall be updated as required) AV Audio Visual, 2 data, see AV design guide section BMS Building Management System, 2 data (typical) CAM Security Camera EM Environmental Monitoring IOT Internet of Things Device NHM Network Health Monitor RSCH Room Scheduler/Calendar Panel SEC Security Device (card access/alertus/etc.) TC Time Clock TEL Telephone outlet, not wall mounted WAP Wireless Access Point WT Wall Telephone, typically 36" – 48" AFF as meets code requirements

Section 27 40 00 – Audio / Visual Systems

1. Caltech Audio / Visual System Standards:

a. The following general descriptions of the functionality of the audio and video systems reflect the programmatic requirements of the owner for the following room types:

1) Lecture Hall
2) Classroom
3) Conference Room
4) Room Divisible Classroom with dual screen projection
5) Classroom Computer Lab

b. General Requirements:

1) Crestron is specified for AV control and signal interfaces. Provide all system engineering and design necessary to develop a complete and operational functioning AV system. The engineering and design shall include preparation of all necessary electronic schematics, infrastructure design, hardware drawings, systems diagrams, schedules, and run lists. Review the final system design and configuration with the owner.

2) Software Programming: Create, load, and test all necessary software setup, configuration, and programming required to develop a complete operating system. Include all control logic and push-button component faceplate or interface programming. Provide to the owner copies of all system programming, both compiled and uncompiled versions, in addition to all graphics files used for touch panel design.

3) Installation: Install all AV system devices, cable, connectors, plates, and other material at the project site. Install the owner furnished equipment and calibrate it to work with the AV system including but not limited to owner furnished computers.

4) Testing and Adjustment: Perform all tests and adjustments, furnish all test equipment necessary, and perform all work required to properly configure the systems and to verify the system performance.

5) Acceptance Testing: Demonstrate to the owner the operation of the complete systems, including all individual devices and control functions. Both subjective and objective tests will be required by the owner to determine compliance with the AV system requirements and the AV system integrator's design.

6) Training: The AV system integrator shall provide technical training of owner's staff, covering AV system operation, maintenance, and troubleshooting. A written set of operating instructions shall be provided.

7) Qualifications: The AV system will be designed by an InfoComm Certified Technology Specialist.

(a) Design (CTS-D) level and built by an InfoComm Certified Technology Specialist
(b) Installation (CTS-I) and Certified Technology Specialist (CTS) team.
(c) The AV system will be programmed by a Crestron certified programmer. Submit the AV system design to Crestron Master Quote for review and recommendations.

8) Supporting Infrastructure and Coordination Low Voltage Cable Paths: The wiring for all AV system components shall be run in ferrous metal conduit. Provide an additional 100% conduit capacity beyond the building code conduit fill requirements for future expansion and flexibility.

9) Provide conduit infrastructure for future expansion from the floor-box at the lectern to the plenum space above the ceiling, or to the equipment rack if the space has a hard ceiling.

10) Coordination: The AV systems will be powered from dedicated circuits, with a dedicated isolated ground and panel board when applicable and/or requested. Coordinate all power locations and load requirements with the electrical engineer. Provide all heat loads and locations to the mechanical engineer for the AV system. Provide all weights and backing requirements for each device to the structural engineer. Provide on-site AV system coordination and infrastructure installation review with the design-builder.

11) **Operation:** The audio and video systems will be designed for automatic operation. The AV system shall be designed so that no operator will be required for daily operations. Design the AV system for remote monitoring and management.

c. Lecture Hall AV System:

1) **General:** The governing design criteria will be to minimize the interaction required by the staff to operate the system, provide flexibility and to minimize the impact of the AV system elements on the architecture. The end result will be a system that is unobtrusive both to the students, the instructors and the operators.
2) **Video Projection:** Video will be displayed with a ceiling mounted video projector and projection screen. The system will be capable of displaying digital video from an HDMI connection. The video projector will have a minimum light output capable of 75 ANSI Lumens per square foot of projected image and a minimum native resolution of 1080P or WUXGA (1920x1200). The motorized projection screen will be sized so that any person in the room will have acceptable viewing of any screen using the following formula: Screen height = 1/5 the diagonal of the room. Locate the bottom of the projection image 4' AFF. The projection screens will have a tensioning system to minimize distortion and a screen gain of .9. The .9 screen gain aids the video projector to produce a higher contrast ratio for higher classroom ambient light conditions. The projection screen image format ratio will match the native resolution of the projector. The projection screen will be recessed above the finished ceiling and finished with a trim ring.
3) **Source Equipment and Input / Output:** The AV system will have inputs at the lectern for HDMI, suitable for both Macintosh and PC. The system will allow for a variety of audio and video source equipment to be inserted into the system on a temporary basis. Locate one auxiliary shelf in the equipment rack with an HDMI connection for a future source that cannot be anticipated at this time. Provide a second auxiliary HDMI connection and an HDMI input on the equipment rack. Locate an HDMI input panel for laptop computer video signals, with associated audio over HDMI, on the lectern or in the millwork depending on the exact room configuration. The lectern AV system connections will be routed through a floor-box to minimize tripping hazards. For other locations there will be a direct connection at the millwork equipment cabinet.
4) **ADA Compliance:** The AV system regardless of location will be ADA compliant. The ADA system will be fixed. There will be no portable ADA compliant devices.
5) **Audio:** A minimum of one lectern mounted microphone and two channels of wireless microphones shall be provided. Each channel of wireless microphone shall have a handheld and lavalier transmitter available. Speech reinforcement shall use a distributed ceiling speaker system. Computer program audio shall use either a dedicated pair of loudspeakers adjacent to the projection screen or be routed through the ceiling speaker system. If loudspeakers are to be mounted adjacent to the screen, the speaker enclosures shall have rated hardware attachment points. The program audio will follow the video switching.
6) **Equipment Location:** Equipment needed to support the AV presentation system will be mounted in an equipment rack, located in an enclosed closet with suitable ventilation, and with direct access from the lecture hall.
7) **User Interface:** A remote control system will be incorporated into the design of the A/V system. It will use a touch panel control interface to provide integrated control of all system functions including system on/off, input source selection, program audio volume, projection screen up/down, audio mute, video mute, and transport controls. The control system should interface with any lighting or shade control system. Submit the touch panel control screen layouts to the owner for review and approval.

d. Classroom: A classroom will receive a scaled version of the lecture hall AV system as required to suit the needs of the classroom. All of the equipment needed to support the AV presentation system will be located in the lectern at the front of the room or in a lockable rack cabinet within the room depending on the exact room configuration. In rooms without casework, provide a lockable AV equipment rack. Contractor to ensure proper locks are installed.

e. Room Divisible Classroom with two Smart Classroom AV systems: Rooms with operable partitions and two smart classroom AV systems will be connected so that when the partition is open the projection system can display the same source or two individual sources. Design a simple user interface page using the control system touch panel to accomplish this task.

f. Computer Lab: The computer classroom will be designed to operate the same as a typical smart classroom with a variation on the configuration. The student's lab computers will be displayed on the projection system with software provided by the Institute.

g. Conference Room and Workroom AV System: Each conference and workroom AV system will be designed as a variation of the typical smart classroom. These AV systems will be different from the smart classroom as follows:

1) There will be no smart lectern.
2) Locate the equipment in a dedicated portion of the built-in lockable storage in an equipment rack enclosure. Make the equipment in the rack serviceable with a slide-out and rotating style equipment rack enclosure.
3) There will be no document camera.
4) Conference rooms will use a flush floor-box located under the conference room table for audio, video, and control connections, AC power, and two data connections to the campus ethernet. Fixed conference tables will have a cable management system in the tabletop.
5) Locate a 10–inch touch panel on the wall for workrooms or on the conference table in conference rooms.

DIVISION 28 – ELECTRONIC SAFETY AND SECURITY

Section 28 10 00 – Access Control and Video Surveillance

The 28 13 00 Access Control System and 28 23 00 Video Management System design guidelines are accessible from a member of the PD&C team. They can find it at the link below, which has restricted access.

SECTION 28 13 00 ACCESS CONTROL SYSTEM

SECTION 28 23 00-VIDEO MANAGEMENT SYSTEM

Section 28 46 00 – Fire Detection and Alarm

1. **General:**
   - **a.** The campus standard fire alarm system is manufactured by Mircom and type FX–2000 series microprocessor-based panels shall be utilized for all new projects — no exceptions.
   - **b.** The fire alarm system design shall comply with all national, state, county, and local codes and standards and should be in full compliance with city of Pasadena Fire Department.
   - **c.** Only fire alarm equipment will be connected / monitored by the fire alarm system. No gas or damper monitoring allowed.
   - **d.** Voice evacuation systems shall be avoided — unless specifically required by code and formal written approval is provided by Caltech Facilities staff.
   - **e.** All door magnetic hold opens shall be 120V.
2. **Control Panel:**
   - **a.** Provide fully automatic fire detection and alarm system. The control panel shall provide power, annunciation, supervision, and control for the detection and alarm system.
   - **b.** The detection system shall remain 100% operational and capable of responding to all alarm conditions while in the routine maintenance mode.
   - **c.** The control panel shall be capable of supporting non-addressable as well as addressable detection devices.
   - **d.** The control panel shall operate from a three-wire 120VAC power supply and internal 24V backup battery. Battery shall be the sealed, lead-calcium type with 25% spare capacity.
   - **e.** The backup battery system shall be sized for 60 hours for supervisory mode and 15 minutes for alarm mode.
   - **f.** The control panel shall have the ability to support a printer terminal.
   - **g.** Control panel shall be equipped with RS–232 port for connection to a MUX Pad 2
   - **h.** System to communicate to a Mux Pad 2 device to communicate with the Caltech proprietary station located at 370 South Holliston.
   - **i.** Only FCI SNAC–9 power supplies shall be used to power annunciation devices.
3. **Annunciation and Wiring:**
   - **a.** Provide LCD type annunciator at fireman's main entry and where required by Caltech.
   - **b.** Provide Class B system, fully supervised.
   - **c.** Minimum wiring used shall be size 14 AWGAWG or larger as required.
   - **d.** Proper size wiring shall be used to limit the voltage drops to 10% at any circuit.
4. **Devices:**
   - **a.** Horns, strobes, and horn / strobes shall be Gentex #GEC3–24WR / GES3–24WR series devices — white in color.
   - **b.** Smoke detectors shall be Mircom #MX–2351AP with a #B300–6 mounting base.
   - **c.** Duct detectors shall be System Sensor #DNR with a #DST5 sampling tube as required.

d. Monitor modules shall be a Mircom #MIX–M501M device.
e. Relay modules shall be a Mircom #MIX–M500R device.

5. Installation:

a. Fire alarm system installer shall have minimum of 5 years' installation experience, shall be certified by NICET and the manufacturer, and shall have a California State License to perform the work.
b. All conductors and wiring shall be installed according to the manufacturer's recommendations and free from ground faults and electrical shorts.
c. All devices shall be labeled with the address on the exterior of device.
d. In general, the fire alarm system shall shut down all HVAC systems.
e. Provide a minimum of 15% of spare devices for each type of device used on the project.
f. Door Holders: Provide all wiring to wall and door mounted door holders. Door holders shall be operated at 120V independent of fire alarm control panel power supply.
g. Installation of backbone for fire alarm system shall have terminal cans no smaller than 18x18x6.
h. All elevator smoke guards shall be operated by a relay module — not a detector-based relay.
i. Place combination fire/smoke damper relay near fire alarm termination and at an elevation not exceeding 6 feet above finished floor.

DIVISION 31 – EARTHWORK

Section 31 10 00 – Site Clearing

Section 31 11 00 Clearing and Grubbing

1. **General:**
   a. Comply with current California Law, Government Code 4216 prior to performing any digging. See www.digalert.org.
   b. Removal of vegetation, grass, grass roots, shrubs, upturned stumps, weed growth, tree roots, brush, masonry, concrete, rubbish, debris, and other materials. Removal of concrete and bituminous surfaces.
2. **Concrete and Bituminous Surface Removal:**
   a. Break up and completely remove existing concrete surfacing, curbs, gutters, walks, and bituminous surfacing to the indicated limits. Cutting shall be performed to a neat and even line with proper tools or a concrete cutting saw. Minimum depth of cut shall be 1½–inch, unless otherwise indicated. Remove concrete broken beyond the indicated limits to the nearest joint or score line and replace with new concrete to match existing.
3. **Cleanup:**
   a. Remove rubbish, debris, and waste materials and legally dispose of off the project site.
4. **Preparation:**
   a. Protect and maintain installed stakes until their removal is required for the work. Provide replacement grade or location stakes lost or disturbed. Install grade stakes and compare to indicated grades. If discrepancies are found between existing grades and grades indicated on drawings, do not proceed until discrepancies are resolved.

31 13 00 Selective Tree and Shrub Removal and Trimming

1. **General:**
   a. Removal of trees and shrubs shall follow Pasadena Municipal Code 8.52.070 and 8.52.075 per the Tree Protection Ordinance. The removal of trees shall include the removal of stumps and roots to the extent that no root greater than 3 inches in diameter remains within 5 feet of any underground structure or utility line, nor under footings or paved areas. Grubbing in open areas shall include removal of stumps 3 inches in diameter, or greater, to 2 feet below finish grade elevations.

31 14 00 Earth Stripping and Stockpiling

1. **General:**
   a. Excess material or topsoil not required, or not permitted as fill, shall be removed from Caltech property at the contractor's expense.

Section 31 20 00 – Earth Moving

Section 31 22 00 Grading

1. **Backfill:**
   a. Material shall be free of debris.
   b. All backfill material to be brought on campus/site shall be from a certifiable source.
   c. Backfill soil certification must be provided to Caltech PM for review and approval prior to delivery.
   d. All graded areas must be protected from runoff in accordance with State Water Resources Board requirements.

31 23 00 Site Utilities, Excavation and Fill

1. **General:**
   a. Comply with current California Law, Government Code 4216. See DigAlert.org.

b. Excavations are not permitted that undermine the integrity of adjacent structures, paving, trees, or utilities.

c. Before excavation, contact Caltech Facilities for information on buried utilities and pipelines. For onsite utilities retain an underground utility identification service (e.g. Goldak, DigAlert, etc.). Perform electromagnetic (EM) locating and/or ground penetrating radar (GPR) scanning to identify underground utilities within the limits of work.

1) Verify location and depth of utilities by **vacuum potholing to the appropriate depth and quantity as necessary**, particularly where excavation occurs within 5 feet of known utilities, at utility crossings, or where utility depth is uncertain. Utilities crossing new work shall be physically exposed by potholing prior to trench excavation to verify elevation and clearance.

2) Where utilities are concealed within slabs, vaults, tunnels, or structural elements and GPR results are inconclusive, utilize X-ray or ultrasonic scanning.

3) When available, Caltech will provide reference drawings upon contractor's written request. **Record drawings are approximate and for reference only. As-built drawings are not available.**

4) The contractor shall be responsible for verifying the exact location, depth, and alignment of all utilities prior to excavation. Failure to perform adequate field verification shall not relieve the contractor of responsibility for damage to utilities resulting from construction operations. The contractor shall assume utilities exist between known points and where utilities typically occur, whether or not shown on the drawings.

5) Where the work includes a building extension or addition on an occupied project site, perform work in such a manner, and at such times, as not to disrupt performance of existing utility services to existing project site facilities. Where an interruption is necessary, obtain review from the campus before proceeding.

d. Remove concrete or bituminous pavement to straight lines by saw cutting.

e. Remove conduits or pipes not in service, exposed during work, unless a minimum cover of 3 feet is provided. Remove concrete, clay, or other non-metallic pipe over 8 inches in diameter, unless otherwise indicated.

2. Protection:

a. Protect and guard excavations against danger to life, limb, and property as required by, but not limited to, OSHA regulations.

b. Provide trench protection systems in accordance with OSHA excavation safety requirements. Trenches greater than **5 feet in depth** shall be protected by shoring, trench boxes, or approved sloping/benching methods. Where required, **shoring systems shall be designed and stamped by a professional engineer**.

c. Protect existing improvements including landscaping against damage. Repair or replace damaged items. Protect existing utility services and distribution systems from damage or displacement. Use hand or vacuum excavation within 24 inches of identified utilities unless otherwise approved. If unidentified utilities are encountered, stop work and notify Caltech PM immediately.

3. Backfill and Compaction:

a. Each layer of fill material shall be compacted by tamping, sheepsfoot rollers, or pneumatic-tired rollers to provide specified relative compaction. At inaccessible locations, provide specified compaction by manually held, operated, and directed compaction equipment.

b. Provide sand bedding and backfill for direct buried utilities — minimum 6 inches sand bedding below pipe, minimum 6 inches sand surround on sides of pipe, minimum 12 inches sand cover above pipe prior to general backfill.

c. Compact backfill to 95% relative compaction in paved areas and 90% relative compaction in landscaped areas, unless otherwise specified. Where conventional compaction cannot be achieved, provide controlled low-strength material (CLSM) or slurry backfill as approved.

d. Install detectable warning tape above buried utilities and provide tracer wire for non-metallic piping systems.

4. Inspection and Testing:

a. The geotechnical engineer, retained by the campus, will inspect and test excavations, sample material quality for testing as set required, and observe installation and compaction of fill materials.

DIVISION 32 – EXTERIOR IMPROVEMENTS

Section 32 10 00 – Paving

1. **Concrete Placement:** Install Portland cement concrete pavement in compliance with Caltech design guidelines.
2. **Roadways:**
   a. **Public Use:** Roadways to be used for public use shall conform to State of California, County of Los Angeles, and City of Pasadena standards.
3. **Parking Lots:**
   a. **Public Use:** Parking lots to be used for public use shall conform to State of California, County of Los Angeles, and City of Pasadena standards.
4. **Pedestrian Plazas and Walkways**
   a. **Public Use:** Sidewalks, plazas, and other site paving for pedestrian traffic to be used for public use shall conform to State of California, County of Los Angeles, and City of Pasadena standards.
   b. **Walking Surface:** Provide slip-resistant walking surfaces on exterior pavement.
      1) Standard concrete color to be "Bisque" by Admixtures.
   c. **Exterior Steps and Ramps:** Ramps sloped at 1:20 or less are preferred to steps. Avoid the use of ramps where the slope would be greater than 1:20. Where practical, provide steps in these cases.

Section 32 33 00 – Site Furnishings

1. **Bicycle Racks:** Custom-fabricated steel pipe rack. Pipe shall comply with ASTM A 53/A 53M, Type F or Type S, Grade A, Standard Weight (Schedule 40). Hot-dip galvanize, after fabrication; comply with ASTM A 123/A 123M for railings. Do not quench or apply post galvanizing treatments that might interfere with paint adhesion. Baseplate shall comply with ASTM A 36/A 36M. Drill baseplates at each end for expansion anchor bolts (two required for each plate). Coordinate design with Caltech Planning, Design & Construction.
2. **Trash Disposal Area:** Each building shall have a designated trash bin enclosure area that will conform to the City of Pasadena waste management program. Shield trash disposal enclosure from building occupants' view whenever possible. Provide two 3–cubic-yard containers; one 3–cubic-yard container for cardboard; and one 3–cubic yard container for trash. Provide a 35–foot minimum turn radius for trash truck access.
3. **Exterior Trash Receptacles:** Provide a 35–gallon precast concrete trash receptacle with exposed aggregate finish, brown lid, and 31–gallon galvanized steel removable liner to match existing containers on campus at main entrance to each building. Manufactured by Doty & Sons Concrete Products, Model LR1601 with Pitch-In Top. Finish: (EX1); Sealer: Non-gloss (ARC2s). Substitutions are not permitted without written approval from Caltech Planning, Design & Construction. Coordinate location with Caltech Planning, Design & Construction and campus Facilities to ensure adequate service access.
4. Exterior Trash Receptable on Elevated Patios: Trash receptacles on elevated patios have a weight minimum due to Santa Ana wind impacts. Coordinate with Caltech Planning, Design & Construction and campus Facilities for approved models for patios above ground floors.

5. **Exterior Recycling Receptacles — Concrete:** Provide precast concrete recycling receptacles by Doty & Sons Concrete Products, Model 26CHL #RR2C2813, three-compartment configuration. Finish to match campus standard. Substitutions are not permitted without written approval from Caltech Planning, Design & Construction. Coordinate location with Caltech Planning, Design & Construction and campus Facilities to ensure adequate service access.

6. **Exterior Solar Trash and Recycling Compactors:** Where indicated on the project drawings, provide solar-powered trash and recycling compactors by Bigbelly, three-compartment configuration, suitable for university campus applications. Coordinate location with Caltech Planning, Design & Construction and campus Facilities to ensure adequate solar exposure and service access. Substitutions are not permitted without written approval from Caltech Planning, Design & Construction.

7. **Exterior Patio Furniture:** Provide the following solid teak products by Kingsley Bate, Ltd. (www.kingsleybate.com):

   a. Round Table: ESSEX TR 42; 42–inch diameter by 29 inches high and/or ESSEX TR 60; 60–inch diameter by 29 inches high.

   b. Square Table: BAINBRIDGE BG 42; 42.5 inches long by 42.5 inches wide by 29.5 inches high.

   c. Chairs: CLASSIC CL 18A (armchair) and/or CLASSIC CL 18 (side chair).

   d. Umbrellas: ACCESSORIES MU 02 (with 2–inch pole); 10–foot diameter.

   e. Bench: HYDE PARK HP 60; 6 feet long.

   The list of patio furniture is the baseline and every project should consult the Caltech project manager and Caltech Grounds and Maintenance prior to the selection of patio furniture.

Section 32 80 00 – Irrigation

1. **General:** Water conservation is an essential part of the campus's image and quality of life. The campus irrigation system is primarily controlled via a Rain Bird Maxicom computerized control system and a weather station located on campus. Caltech is in the process of updating the central irrigation control system to the Calsense CS3000, a cloud-based, advanced, smart irrigation management system.

2. **New irrigation — Areas impacted shall:**

   a. Whenever a main supply line is installed or redirected, it must be located 18 inches deep minimum. Lateral lines located a minimum of 12 inches deep.

   b. Ball valve at point of connection.

   c. Ball valve at remote control valves when possible. When not possible, isolate 2 RCC's with a ball valve.

   d. Control valve wires. Add an extra wire from controller to each remote control valve.

   e. PVC fitting and nipples at 3 inches minimum distance between all PVC fittings and nipples.

   f. Sprinkler spacing shall be at 12 feet maximum.

   g. Turf sprinklers shall be 2 inches from curbs, walls, and walkways.

   h. Shrub sprinklers shall be 12 inches from walls and 2 inches from walkways and curbs.

   i. Controller shall be the Calsense CS3000 (or newer) including the cellular kit with a master control valve and flow sensor. This installation must be verified by a Calsense representative to ensure warranty.

   j. Drip irrigation must be approved by Caltech Grounds. No drip system on lawns.

k. Quick coupler devices every 50 feet.

l. Installation of ball valve before every remote-control valve for emergencies.

m. SCH80 pipe used before and after remote control valves, ball valves, gate valves, etc.

3. **Materials:** The following materials have been identified for use to maintain consistency with the campus irrigation standards:

a. Controller: Calsense CS3000 or newer

b. Flowsensor: Rain Bird

c. Master control valve, electric: Superior — Normally Open (model 3100)

d. Remote control valves: Rain Bird (PEB/PGA)

e. Drip remote valve assembly: Rain Bird.

f. Nozzles: Rain Bird 1800 series

g. Bubbler heads: Rain Bird – Adjustable full circle 1300A–F, Full circle 1400 series

h. Pop-ups: Rain Bird

i. Rotors: Rain Bird – 5004 series

j. Swing joints: Marlex 90 degree w/schedule 80 nipples

k. Valves: Plastic (Rain Bird) (no brass)

l. Marlex Street Ells

m. Nipples: Schedule 80

n. Ball Valves: Schedule 40

o. Fittings: Schedule 40

p. Quick coupler: Rain Bird 33DLRC

q. Primer: Weld-On P-70 primer

r. Glue: Christy's Red Hot Blue Glue or Christy's Gray PVC Pipe cement (SCH80, PVC>1.5")

s. Superior Actuators: plastic (no brass)

t. Anti-Siphon valves: brass

u. Lateral lines: Schedule 40

v. Main lines: Schedule 40

w. Sleeve piping: Schedule 40

x. Irrigation Meter: Elster DC#70 positive displacement – gallons (no pulsar)

y. Valve box color: green color and place in an inconspicuous location

z. Rotary nozzles: Rain Bird R-Van or Hunter MP Rotator

4. Construction Requirements:

a. Install temporary water submeters to monitor construction water usage. Submit water usage records and summary reports to Caltech PM at project closeout.

b. Document existing irrigation systems and landscape conditions with photographs prior to construction. Restore or replace any damaged irrigation components, planting, or landscape improvements in kind.

Section 32 90 00 – Planting

1. General:

a. Select plant materials from Caltech's Plant Palette found in APPENDIX XIX.

b. It is desirable to save existing trees whenever possible. During the design phase, the design professional shall identify those trees to be saved and those that must be removed. Trees that may be damaged by construction to the point that they have little chance to survive shall be considered for removal.

c. The Campus Landscape Programming document dated 29 October, 2010, is not current. However, it does provide an overview of Caltech's design intent and priorities. The landscape design professional is not required to conform to this document; however, reading this document will help inform any proposed design approach.

2. Plant Maintenance:

a. Provide protective barriers outside the drip line of trees to protect existing trees during construction. As a general rule, provide 1 foot of diameter for each inch of trunk diameter. Install barriers prior to commencement of demolition / construction operations and maintain until substantial completion. Do not store construction material, debris, or excavated material within the barricade area.

b. Protect root system from flooding, compaction, erosion, and noxious materials from spillage of construction materials.

c. Do not allow exposed roots to dry out before backfill is placed; provide temporary earth or moist burlap cover.

d. Repairs to damaged trees shall be performed by a certified arborist.

e. Landscaping included in the scope of work shall be maintained by the contractor, and shall include, but not be limited to watering, fertilizing, and cutting consistent with general practice of care for type of plant material. Tree maintenance shall comply with ANSI A300 standards. Maintenance period shall extend from commencement of on-site operations to the end of the warranty period. After final completion, routine mowing and watering may be performed by Caltech. However, the contractor shall remain responsible for all warranty requirements.

DIVISION 33 – UTILITIES

Section 33 10 00 – Water Utilities

1. General:

a. Consult Caltech project manager regarding information specific to water supply on campus.

b. Paint all exposed pipes in landscaped areas green, except tamper switches and brass stem on backflow preventers.

c. All new backflow devices added to a project must be permitted and tested; test report shall be sent to the city. A hard copy of the test report shall be provided to the Caltech PM in both hard copy and PDF format for our records.

Section 33 30 00 – Sanitary Sewer

1. General:

a. Consult Caltech project manager regarding information specific to sanitary sewer on campus.

Section 33 40 00 – Stormwater Utilities

1. General:

a. Consult Caltech project manager regarding information specific to storm sewer on campus.

b. All catch basins must be properly labeled per State and Caltech requirements.

Section 33 50 00 – Natural Gas Utilities

1. General:

a. The entity providing the trench is considered the trench owner and is responsible for all local ordinance, permit, and resurfacing.

b. The trench must comply with CPUC and DOT regulations and with SoCalGas trench specifications, as applicable.

c. Only dry utilities (power, telephone, CATV, street lighting) are allowed in joint trench with natural gas.

d. No wet utilities (water/sewer/landscaping) are allowed in a joint trench with natural gas.

e. Separation for natural gas utilities:

1) At least 60 inches of undisturbed earth must separate a dry utility trench from a wet utility trench.

2) Power/electric, when located in a joint trench, shall be provided with a minimum of 12 inches of separation in all directions.

3) CATV, telephone, and other dry substructures, when located in a joint trench, shall be provided with a minimum of 12 inches of separation in all directions.

f. Depth or cover over natural gas pipe/line for new installations:

1) 30 inches minimum cover on private property (24 inches if conditions warrant — SoCalGas approval required)

2) 30 inches minimum cover to finished grade when behind curb (parkway) in public easement

3) 30 inches minimum cover to finished grade (flow line) when in street (between curbs) in public easement

4) 32 inches minimum cover for 4–inch and larger diameter pipe

5) 42 inches maximum cover to finished grade in street/ public easement.

g. Trench width for natural gas pipe/line; Refer to Figure 12 — SoCalGas Trench Diagrams in the SoCalGas Natural Gas Service Guidebook for additional information.

1) 18 inches minimum width for 2–inch or smaller diameter natural gas-only pipe trench

2) 24 inches minimum width for greater than 2–inch natural gas-only pipe trench

3) 18 inches minimum width for 5 feet adjacent to coupling

4) 24 inches minimum width at service to main connection

h. Bedding for natural gas pipe/line:

1) 6 inches minimum bed of rock and debris-free sand (screened sand)

i. Backfill material for natural gas pipe/line

1) 12 inches minimum cover of rock-free sand (screened sand) over natural gas pipe in normal soil

2) 18 inches minimum cover of rock-free sand (screened sand) over natural gas pipe in rocky soil

3) Native backfill is encouraged to complete backfill

j. Warning Mesh:

1) SoCalGas requires a warning mesh be installed at a minimum of 12 inches above its natural gas pipeline for pipeline operating at 60 psig or below, and 18 inches above natural gas pipeline operating above 60 psig.

Section 33 60 00 – Hydronic and Steam Utilities

1. General:

a. Consult Caltech project manager regarding information specific to heating and cooling distribution on campus.

b. Hydronic and steam utilities on campus are generally located within the campus utility tunnel system.

c. All new hydronic and steam utilities shall be provided to buildings/facilities via extension of the campus utility tunnel system unless otherwise approved by the Caltech project manager. Direct-buried hydronic and steam utilities are prohibited unless written authorization is provided by the Caltech project manager.

d. Paint all exposed pipes in landscaped areas green. Ensure painting system is suitable for the surface temperature of the piping system. Where exposed piping is insulated, provide with green PVC jacket.

Section 33 70 00 – Electrical Utilities

1. General:

a. Consult Caltech project manager regarding information specific to electrical distribution on campus.

2. Burial Requirements: Per the California Electrical Code, latest version – Table below.

TABLE 300.5 Minimum Cover Requirements, 0 to 1000 Volts, Nominal, Burial in Millimeters (Inches)

Location of Wiring Method or Circuit	Type of Wiring Method or Circuit									
	Column 1 Direct Burial Cables or Conductors		Column 2 Rigid Metal Conduit or Intermediate Metal Conduit		Column 3 Nonmetallic Raceways Listed for Direct Burial Without Concrete Encasement or Other Approved Raceways		Column 4 Residential Branch Circuits Rated 120 Volts or Less with GFCI Protection and Maximum Overcurrent Protection of 20 Amperes		Column 5 Circuits for Control of Irrigation and Landscape Lighting Limited to Not More Than 30 Volts and Installed with Type UF or in Other Identified Cable or Raceway	
	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
All locations not specified below	600	24	150	6	450	18	300	12	150[a, b]	6[a, b]
In trench below 50 mm (2 in.) thick concrete or equivalent	450	18	150	6	300	12	150	6	150	6
Under a building	0 (in raceway or Type MC or Type MI cable identified for direct burial)	0	0	0	0	0	0 (in raceway or Type MC or Type MI cable identified for direct burial)	0	0 (in raceway or Type MC or Type MI cable identified for direct burial)	0
Under minimum of 102 mm (4 in.) thick concrete exterior slab with no vehicular traffic and the slab extending not less than 152 mm (6 in.) beyond the underground installation	450	18	100	4	100	4	150 (direct burial) 100 (in raceway)	6 4	150 (direct burial) 100 (in raceway)	6 4
Under streets, highways, roads, alleys, driveways, and parking lots	600	24	600	24	600	24	600	24	600	24

3. Excavation:

a. Prior to excavating, the California One Call law requires any person planning to conduct any excavation to contact Underground Service Alert, at least two working days (48 hours), but not more than 14 calendar days, prior to commencing that excavation. Dial 811 for Underground Service Alert.

b. Protect existing utility lines from damage or displacement. Remove conduits or pipes not in service, exposed during work, unless a minimum cover of 2 feet is provided. Remove concrete, clay, or other non-metallic pipe unless otherwise indicated.

c. Trenches over 5 feet in depth shall conform to Cal/OSHA.

d. Do not install backfill until required inspections and testing is completed.

4. Conduit:

a. All conduit shall be carefully aligned and laid to a uniform grade as specified on the plan or profile of working drawings. A slight degree of snaking will be permitted with flexible and semirigid plastic conduit. A minimum conduit coverage of 24 inches will be maintained unless otherwise specified by code.

b. No conduit will be installed that is cracked, damaged, or contains any roughness that would injure the cable jacket.

c. All questionable conduit to be installed will be tested for passage of mandrel prior to installation. Any conduit not permitting passage of mandrel will be rejected.

d. All conduit banks requiring concrete encasement will be adequately held in place to prevent floating during installation.

Section 33 80 00 – Communications Utilities

1. General:

a. Consult Caltech project manager regarding information specific to communications distribution on campus.

b. Refer to DIVISION 27 – COMMUNICATIONS for specific requirements.

APPENDIX I - UPDATE / REVISION LOG

Online summary of changes

Version #	Issue Date
V.1	May 2012
V.1 Revised	October 2012
V.2	March 2013
V.3	October 2014
V.3.1	December 2014
V.4	February 2018
V.5	September 2020
V.5.1	October 2020
V.5.2	April 2021
V.5.3	November 2021
V5.4	April 2024

V5.5 September 2026

APPENDIX II – SUBMITTAL REGISTER

See link: Caltech Facilities Submittal Register

APPENDIX III – PROJECT CLOSEOUT CHECKLIST

Substantial Completion

Post-performance period, all systems tested and working properly, no major outstanding issues:

☐ Punchlist/deficiencies have been identified and are captured in a list with anticipated completion dates. Below are most, but not all, systems that must be complete and who the reviewing party will be for Caltech to validate:

COMPLETED	N/A	
☐	☐	HVAC – CxA • Pre-functional complete, TAB complete, hydronic balance complete
☐	☐	Plumbing – Caltech and City of Pasadena • Fixtures operational, pumps functioning, chlorination, flush (DI water)
☐	☐	Lab gases – Caltech shops (plumbing)
☐	☐	Lab Equipment – Caltech • Schedule PM to walk after final installation. • Show Caltech equipment is functioning as intended
☐	☐	Vacuum Equipment – Caltech shops (plumbing), Startup + training
☐	☐	Fume hoods – ISEC to submit Balance Certification + ASHRAE 110-2016,
☐	☐	Power monitoring – Caltech shops (Alex Sanchez/Controls and Richard Bravo, David Feldser/Electrical and Manager of Maintenance Management/Director of Infrastructure and Maintenance)
☐	☐	A/V – Caltech (Becca Rose/AMT and IMSS POC, J. Monaly) • Paul W. to confirm with Becca what testing/certifying will be done to accept A/V system. Ask for checklist.
☐	☐	Lighting Control – Caltech (Alex Sanchez/Controls and Richard Bravo, David Feldser/Electrical and Rene)
☐	☐	IT – Caltech (Joe Monaly)
☐	☐	Security – Caltech (Hampton Cantrell/Chief of Security and Alex Ferrari/Lock Shop)
☐	☐	Door Hardware – Caltech (Alex Ferrari/Lock Shop)
☐	☐	Fire Alarm – Fire Marshal and Caltech (Fire Alarm Lead) • Fire Alarm Lead first • Fire Marshal after
☐	☐	Fire Pump – Fire Marshal • Determine what is required to accept our fire pump
☐	☐	Hardscape path of travel/accessible – City of Pasadena
☐	☐	Landscape – Caltech (Delmy Emerson/Buildings & Grounds) • Review approved tree list with City and location on site at final walk
☐	☐	Check with City of Pasadena if there are any outstanding fees or open permits
☐	☐	Laboratory User Guide w/ appropriate contents (Max Christman/Sustainability)

☐ **All work complete per Contract Documents**

- With exception of minor punchlist items and furniture

☐ **Project ready to use by Caltech**

- Building functions as intended

☐ **Caltech to provide a "Certificate of Substantial Completion"**

- GC to issue letter formally requesting substantial completion from Caltech. Includes list of punchlist items
- GC to issue letter formally addressing the 1–year warranty period

☐ **Final Certificate of Occupancy**

Final Completion (90 days after Substantial Completion)

☐ **All punchlist/deficiencies corrected and completed**

☐ **Caltech provides letter confirming complete**

GC to issue letter requesting Final Completion with requested Date

- Attach completed punchlist items
- Attach CxA's "Certificate of Completion" for commissioning
- Attach retention billing for Final Payment including all required releases

Caltech accepts the Work as a fully-functioning Project

☐ Commissioning 100% complete

- CxA provides Certificate of Completion

☐ BMS renaming complete

☐ owner trainings complete

- Caltech to define what training needs to be video taped

☐ Schedule 11–month post-Cx walk starting from the warranty period

☐ Asset Management & Issue Logs

☐ **Certificate of occupancy received**

☐ **Applicable administrative agencies have approved the work to achieve required certification**

Closeout Deliverable Documents Submitted (use Caltech approved file naming for all documents):

SUBMITTED	N/A	DOCUMENT NAME	DELIVERABLE FORMAT
☐	☐	HVAC – CxA	
☐	☐	As-builts	Native files and PDF
☐	☐	Permit set	Native files and PDF
☐	☐	O&M manuals	PDF
☐	☐	TAB reports	PDF
☐	☐	Warranties	PDF
☐	☐	Construction Submittals and RFIs	PDF
☐	☐	Basis of Design	Native files and PDF
☐	☐	Specifications	Native files and PDF
☐	☐	Commissioning reports/logs	Native files and PDF
☐	☐	Site/Soil surveys	PDF

- Geotech reports and/or completed inspections during construction

SUBMITTED	N/A	DOCUMENT NAME	DELIVERABLE FORMAT
☐	☐	Calculations and diagrams • • • • • (i.e. Luminosity calculations)	Native files and PDF
☐	☐	Hazmat Reports, Certifications, Manifests	
☐	☐	Test Reports and Certifications	
☐	☐	Updated room square footage information and cost breakdown by room	
☐	☐	Handoff Form to Ops (Internal)	
☐	☐	Cx Readiness Form (CxA to provide)	
☐	☐	Daily and/or Weekly Field reports	
☐	☐	Caltech Internal Completed Inspection Form (Internal from Caltech Inspector)	
☐	☐	Permit Records and Fees	
☐	☐	Approved Baseline CPM Schedule	
☐	☐	Final Change Order Log	
☐	☐	Other specialty documents or drawings _____	

APPENDIX IV – LIST OF NONASSIGNABLE SPACES

Non-Assignable Areas

The following areas are typical non-assignable areas. These areas should be incorporated into new construction and major renovations. Non-assignable spaces are those areas within a building that are essential to the operation of the building but not assigned directly to people or programs.

- Private and Public Restrooms (include bathrooms)
- Wellness or Lactation Room
- Custodial Rooms
- Mechanical and Electrical Rooms
- IT Data Rooms and Server Rooms
- Corridors and Circulation areas
- Lobbies
- Stairwells
- Elevators and Elevator Machine Rooms
- Exterior Building walls
- Mechanical Shafts

APPENDIX V – CALTECH INSPECTION PROCESS

Caltech Inspection Processes Guidelines

The information below addresses the processes used by the Caltech Building inspector. The Caltech inspector shall inspect all projects. The construction contractor and design-build team shall coordinate inspections with the inspection throughout the course of the project. The Facilities Operations & Services shops staff shall also inspect all projects. Sign off by both the shops staff and the Caltech inspector is required to complete all projects. Coordinate the required shops walks with the Caltech project manager. Prior to the shops "Sign off", the issue logs (Cx Issues Log/CPPM Issues) must be resolved. Open items in the issues log will not allow sign off.

1) The Pre-Construction Meeting (Kick-off):

    a) Caltech PD&C Team will set up the Pre-Construction meeting to discuss inspection, processes, and a tailored list of inspections, these inspections shall be shown on the Caltech Quality Control (QC) Inspection Card.
    b) Caltech QC card(s) and Inspection Templates will be brought to the meeting and shared with the contractor.
    c) Note that the Caltech inspector is not affiliated with the City of Pasadena, it is solely the contractors responsibility to schedule and satisfy the City of Pasadena Building & Safety Department, building inspection procedures determined by the City.
    d) It is the contractors responsibility to satisfy the permit card issued by the City of Pasadena and the Caltech QC Inspection card issued by the Caltech PD&C Team (Planning, Design & Construction Team).
    e) Caltech QC Inspection Card shall not supersede the permit card issued by the City of Pasadena.

2) Inspection Requests: Inspection and re-inspection requests are the responsibility of the applicant. The applicant shall request an inspection by utilizing a MS calendar invite and copying the Caltech project managers or contacting the Caltech inspector at (626) 395-1747, this includes re-inspections.

    a) The Caltech inspector requires a 24 hour-notice prior to inspections.
    b) The contractor should call for a normal, signature final and project final when the work is ready for inspection.
    c) Special inspectors shall be contracted by Caltech for all projects. In cases where the special inspector has completed an inspection and another inspection is needed for the same scope, the Caltech inspector shall verify the requested area of work.
    d) Caltech inspector shall not direct work and shall verify compliance with applicable codes and Caltech design guidelines.

3) Signing of the Caltech Quality Control (QC) Inspection Sign-off Sheet (Job Card): Caltech inspector signs Caltech QC inspection card as the inspections are closed during construction.

   a) Normal inspections are called for by each inspection type (Structural: Walls, Mechanical: Exhaust, Electrical: Labeling, Torque Verification etc.) and will result in signing the back of the card.
   b) Signature inspections are requested under the inspection type final (Structural Final, Mechanical Final, Electrical, Plumbing Final).
   c) Project final inspection and related partial approvals will be under “Final Inspection" type.
   d) If failed, inspection will remain open until new inspection request is scheduled and approved.

4) Construction Issues Log: Construction activities performed that deviate from the approved documents shall be logged and tracked in the Autodesk Forma (ACC). The Caltech inspector shall populate the issues log under Forma and share the log with the contractor(s) and associated Caltech project manager via email. The issues log in Forma will be used to track inspector issues on an ongoing basis.

5) Non-compliance Notice(s): Caltech inspector to issue a Non-compliance Notice if the issues are not corrected in a timely manner. Non – compliance Notices will be shared with the contractor and project manager via-email and posted in the project folder.

   a) Non - compliance Notice(s) are to capture deficiencies to the extent possible within the appropriate time. If the Caltech inspector has additional time to spend on the inspection they will continue to capture deficiencies as they are visible.

6) Inspector Notes on Field Drawings: The Caltech inspector shall make notations on the required field set and shall be made available by the contractor to provide another record of inspection activity. Note: The drawings are required to be made available to the inspector.

7) RFIs and Inspection Requests: Inspections requests that have an associated RFI shall reference the RFI number in the Inspection Request by the contractor to the Caltech inspector.

   a) Contractor shall present the associated approved RFIs to the Caltech inspector in the field at the time of inspection.

8) Special Inspections:

   a) The special inspection agency is to provide timely special inspection report(s) by email or utilizing a shared drive furnished by the contractor.
   b) The special inspection agency should complete written inspection reports for each inspection visit and provide the reports to the Caltech inspector and the Caltech project manager on a timely basis. These reports should be organized in a format that can be submitted daily or as otherwise determined by Caltech project manager and Caltech inspector.

c) The contractor shall distribute all special inspection reports to the Caltech inspector and the Caltech project manager for review. Any issues found during the review of the report will be brought to the immediate attention of the special inspection agency and the applicant as necessary.
d) Special inspection affidavit provided at final project inspection.
e) Special Inspections may be performed by the Caltech inspector, depending on the size and scope of the project. This will be determined by Caltech inspector and Caltech project manager with the approval of the City of Pasadena.

9) In Progress Special Inspections:

a) In the case where the inspectors time is limited due to other scheduled inspections, the inspector shall perform the in-progress inspection up to 1 hour. If the there is a high demand for inspections, in progress inspections shall be limited to 2 per day in the order scheduled unless the inspection is a critical request
b) A Forma Construction Issues log entry shall not be issued as a result of an in-progress inspection.
c) Progress inspections shall be held in an open status until associated scope is complete and closed.

10) Field resolution process or Appeals Process:

a) In cases where applicant does not agree with inspectors findings:
b) Resolve matter with the Caltech inspector, this should be the primary method of resolution.
c) Email the associated Caltech project manager with request for field resolution and copy the Caltech inspector.

11) Project Closeout Sequencing:

a) Applicant to request an inspection for required commissioning.
b) This would be noted as a normal inspection, add notes to designate commissioning related inspection in request.

12) Pre-final Inspection Meeting and Project Walk:

a) Approx. 7 days before the request for the project Final Inspection, a Pre-final inspection meeting/project walk shall be held with the Caltech inspector, Caltech project manager and Caltech Facilities.
b) Applicant shall have the red lined drawings available at pre-final walk and final inspections.

13) Signing of Caltech QC Inspection Card:

a) Applicant shall achieve the required inspection signatures on QC Inspection Card before requesting final inspection.
b) The Caltech inspector signs off on permit card at project final.

14) Additional QC Inspections:

a) Monitor / verify that all newly installed construction is in compliance with applicable building codes (CMC, CPC, CBC, NFPA, etc.).
b) Execution of work, all items shall be installed in a neat and workmanlike manner.
c) Verify / observe pressure testing of duct work. Caltech representation is required.
d) Verify testing parameters and observe pressure testing of dry and wet utilities. Caltech representation is required.
e) Observe cleaning chemical treatment of pipes. Caltech representation is required.
f) Observe / verify seismic supports and components. Caltech representation is required.
g) Random examination of TAB subcontractor's work.
h) Monitor installation to ensure it conforms to Caltech's DG requirements.
i) Site prep work, verify subgrade conditions and elevations prior finishes.
j) Verify material(s) upon delivery and during installation, domestic manufacture versus imported.
k) Refer to Division 22 and Division 23 for pressure testing requirements.

15) Hot Work Permits:

a) Required for any spark producing operations.
b) To issue a Hot work Permit, contact the Caltech inspector, project manager or designated PAI, inform them of the Hot work to be done and provide specific information, such as: work being completed, specific location, and dates / length of time of work.
c) The Hot work Permit shall not be valid for a period exceeding 24 hours; each spark producing task will require an additional Hot work Permit.
d) It's the responsibility of the Hot work Permit Holder to return the permit once work has ceased and fire watch operations are complete.
e) Prior to start of Hot work operations – Review and complete required precautions checklist, emergency contact information, and post the Hot work Permit immediately outside the designated work area.

APPENDIX VI – PHOTOGRAPHIC DOCUMENTATION

See Section 01 3233 Photographic Documentation

APPENDIX VII - A NOTE ON EARTHQUAKE DESIGN OF CALTECH BUILDINGS

Kalman Lee Benuska, P.E., S. E.

History

For a period of about 30 years Caltech required new buildings to be designed for 50% additional lateral forces (over code values) and review of the seismic structural design by the structural engineering faculty. However, the design requirements for each of Caltech's last three major buildings, Cahill Center, Annenberg Center, and Schlinger Laboratory, did not include an increase in lateral forces over those prescribed in the California Building Code. Caltech's special seismic design requirements, however, did continue to include review by structural engineering faculty. The applicable editions of the building code and the referenced seismic provisions are in parenthesis as follows; Cahill Center (2001 California Building Code (CBC), 1997 Uniform Building Code (UBC)), Annenberg Center (2007 CBC, 2006 International Building Code (IBC)), and Schlinger Laboratory (2007 CBC, 2006 IBC).

Summarizing Caltech's history of increased lateral forces, Prof. Paul Jennings writes; in 1965, after the Alaskan Earthquake of 1964, George Housner wrote a note entitled Earthquake Design Considerations for Caltech Buildings. In this note he recommended that Caltech buildings should be designed for lateral forces 50% larger than those specified by the Uniform Building Code. Presumably he sent this to the administration then. Also, I recall George telling me about this time that he and Don Hudson had looked at the plans of all of Caltech's older buildings to judge their earthquake hazard … In 1979, George wrote a memo to Bob Fort, the Director of Physical plant, reminding him that that Caltech has used more stringent earthquake requirements than appear in the building code and that he and I had reviewed the design of a building before it was let out to bid … … [Paul Jennings, EQ Resistance of Caltech Buildings, email to Ken Hargreaves and others, May 21, 2010].

The earliest record of a building design incorporating this 50% increase is in Facilities' building data base for Baxter Hall. Using the provisions of the 1967 UBC, Baxter Hall's preliminary structural design was completed in mid-1967, final design was completed in early 1969, and the building was occupied in 1971. For the 1969 final design the "C" factor was increased from 0.10 to 0.15.

This simple addition of 50% more lateral loads morphed into an Importance Factor of 1.5 for subsequent buildings. Braun Laboratories (1976 UBC), Watson Laboratories (1976 UBC), Beckman Institute (1985 and 1988 UBC), Avery House (1991 UBC), Moore Laboratory (1991 UBC) and Sherman Fairchild Library (1991 UBC) all increased the code required Importance Factor to 1.5 from 1.0. The first use of unmodified code lateral forces was the Wilson South Parking Structure, using the 1997 edition of the Uniform Building Code.

Important code changes initiated in the 1997 UBC support the decision to abandon the simple addition of 50% more lateral force. Site-specific soil amplification characteristics defined by average neat surface shear wave velocity were introduced as a Soil Profile Type in the 1997 UBC[1]. The 1997 edition also included the distance to the nearest fault, its capability to produce a large magnitude earthquake and the historical rate of seismic activity on the fault which, combined with the soil profile, prescribed an effective seismic force about 43% larger than the seismic coefficients required by building codes for earlier buildings on campus[2].

Furthermore, additional code developments after the 1971 M_w 6.7 Sylmar, 1989 M_w 6.9 Loma Prieta and 1994 M_w 6.7 Northridge earthquakes resulted in new building structures better able to resist future earthquakes. Notable improvements culminating in the 1997 Edition of the Uniform Building Code include better estimates of strong ground motions, accounting for the behavior of rock and soil foundations, the requirements of ductile structural members and their connections and reinforcement of stiff building structures.

Recommendations for Future Buildings

Applicable Building Code

2019 California Building Code, Title 24 Part 2, or later edition

Quality Assurance

The cornerstone supporting an active and serious concern about the earthquake performance of Caltech's buildings has been and will continue to be active participation by structural engineering faculty. This participation has the effect of a Quality Assurance (QA) program. It is a systematic monitoring during design of the earthquake performance of a building, through discussion and analysis, to ensure that standards of good performance are being met.

The Process

- Select appropriate faculty member or members for the building project.

- Faculty member(s) and Caltech Facilities meet with project design engineer during design development phase to discuss Caltech's special seismic performance requirements and express any special concerns. The Faculty may require some analyses that help insure that the structure has the needed capacity. The Caltech project manager or their delegate may attend this meeting.
- A second meeting is held to review the final design, the results of any special analyses that the Faculty has requested, such as a dynamic analysis or a push-over study, and any special problems or features of the building. This is typically the last opportunity Faculty has to influence the structural design. The Caltech project manager or their delegate will attend this meeting.
- The Caltech project manager or their delegate will review the structural plans for special seismic features before the plans are released for construction.

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[1] Twenty years earlier, the 1976 USC had increased lateral building forces with a site-structure resonance coefficient dependent upon the ratio of building period of vibration to a characteristic site period. The site period was determined by geotechnical data that proved to be overly subjective for effective code enforcement and consequently, the 1988 UBC substituted a site coefficient representing soil amplification of seismic lateral forces. The near surface soil profile was determined by geotechnical data for type and stiffness of the subsurface soils. By the mid-1990s geophysical research using arrays of strong motion records lead to a definition of near surface *Soil Profile Type* using site-specific average shear wave velocity in the upper 100 ft.

[2] C_a = seismic coefficient, a function of Seismic Zone Factor Z=0.4, Soil Profile Type s_D, closest Distance To Seismic Source 1.6 km, Seismic Source Type B. UBC Equation 30-5, $C_a = 0.44 \times 1.3 = 0.572$, therefore, increase of C_a over K is [1-(0.572/040)] =+43%.

APPENDIX VIII – FM Global Review Process

THE HPR CARRIER PLAN REVIEW PROCESS: Most major contractors working with larger institutions and major companies are familiar with the owners casualty insurance carrier plan review process, although some smaller companies and contractors that do not do much construction for major institutions insured in the HPR marketplace may not be. The intent is to add value to the project and catch pre-installation and design errors before systems have actually been installed.

The process outlined below is a general process and may vary based on project schedule and scope.

The general process for involving FM Global in the project is outlined below:

1. At the start of design and start of construction, ensure vendors know that FM guidelines are required to be met and subject to FM review and approval. A major focus of this review is on fire protection. See the FM Global website for these requirements, https://www.fmglobal.com/research-and-resources/fm-global-data-sheets.

2. All design documents shall state that "Plans and specifications shall be submitted for review and approval by our property insurance carrier's (FM Global) engineering department during design and prior to installation."

3. At the start of the project the PM shall arrange a meeting with the project team and the FM engineer assigned to the project, to go over the scope of the project and get input on required specifications.

4. The FM engineer will draft a letter outlining specific requirements, such as sprinkler system densities for different areas, types of systems to be installed, special protection for special hazards, fire separations for areas with hazardous or critical occupancies, etc. They may also research the existing water supplies and/or conduct hydrant flow tests to provide the data on which the sprinkler system calculations should be based. The FM engineer shall identify which types of plans for the project they will want to review and at which milestones; this can include sprinkler system or special extinguishing system design, alarm systems, electrical systems, roof drainage, and even structural plans, depending on the project.

5. Note that if there is disagreement with the protection being specified, the time to negotiate alternatives, in order to make sure that decisions that are made do not negatively affect the insurance rating, or the level of protection provided for your property, is during the design process before construction award.

6. Design documents as determined in the letter from the FM engineer are forwarded to the FM engineer by the Caltech project manager for review and approval. If information is not included in the plans, or if there appears to be an error in the calculations, the engineer will generally call the Caltech project manager to get the item remedied. If the item cannot be resolved in this manner, the engineer will draft a letter indicating why the plans cannot be approved, so that remedial action may be taken, or missing information forwarded.

7. Once the plans have been reviewed and approved, a plan review letter will be issued to the Caltech project manager.

8. During construction/installation, at critical points in the project, the FM engineer will typically perform a project walk to verify that the installation is going according to plans, to witness acceptance testing of pumps, underground mains, and special extinguishing systems, and sprinkler hydrostatic testing, and to update the underwriter on the status of the project. The FM engineer will also look for fire hazards on the jobsite.

9. After the project is completed, the FM engineer will send a letter to the Caltech project manager stating that a satisfactory field inspection has been conducted and the installations found acceptable. This letter is filed in the

project folder.

One final note: sometimes FM's recommendations may be for design over and above code requirements. Remember that codes are minimum standards — the minimum design that a contractor would legally be allowed to use. Often these standards are primarily for life safety, and do not result in a high degree of protection for the building and its contents. Depending on the importance of a facility, it will often make sense to design to a higher standard. Additionally, the carrier standard making process (and especially FM's) is much faster and more responsive to new technology, recent problems, and current testing than the national codes, so often new items being incorporated into carrier standards will be incorporated into the National Fire Codes some 5–10 years down the line.

Projects that require FM Plan Review:

- New buildings being constructed (not counting non-sprinklered sheds);
- Additions to sprinklered buildings when the size of the addition is greater than 2000 square feet or where the cost of the addition will exceed $500,000;
- New sprinkler installations;
- Installations of special extinguishing systems, such as pre-action sprinkler systems, gaseous agents, water mist systems, wet or dry chemical extinguishing systems;
- Installation of special detection systems designed to reduce the loss to property, such as early warning smoke detection;
- Renovations involving an increase in hazard, for example, changing from an office or classroom occupancy to laboratory, equipment, or storage area;
- Installation of new or additional equipment such as solar panel installations, energy storage systems;
- Addition or remodel of areas or equipment involving special hazards, such as use or storage of flammable liquids, pyrophoric or flammable gasses, hot work, or similar equipment;
- Remodels of sprinklered buildings where a significant enough amount of the sprinkler piping will be exposed that it would make sense to upgrade existing seismic bracing for sprinklers to meet current code;
- Modifications to areas where Caltech may wish for additional input to minimize concerns for potential water damage from fire extinguishing systems, regardless of size of project;
- Addition of new boilers and other gas-fired equipment;
- Re-roof or other exterior renovation where combustibility may contribute to exterior fire spread.

Projects that do not require FM Plan review:

- Minor renovations involving relocation of 20 or fewer sprinklers;
- Renovations focused on modifying air conditioning, domestic plumbing, or updating décor;
- Changes to alarm systems that are provided primarily for life safety, rather than property protection (such as manual pull stations and smoke detectors) and other life safety equipment;
- Renovations to existing non-sprinklered buildings, where there are no plans to provide sprinkler protection or other special extinguishing systems.

APPENDIX IX – Office Renovation Guidelines for New Professorial Hires

Office renovations shall comply with the latest version of the Caltech design guidelines.

- These guidelines provide guidance on office renovations for new professorial hires. Existing professorial faculty, non-professorial faculty, postdoctoral scholar, and student offices are not included in these guidelines.
- Work and furnishings covered by renewal funds shall not exceed $20,000.
- These guidelines apply to stand-alone new faculty office renovations not tied to larger renovation or construction projects.
- Office size is typically 180 to 220 square feet.
- The work is planned and implemented in compliance with the applicable building code regulations, fire code regulations, and ADA guidelines.

The work that can be completed is as follows:

1. Paint walls and install new carpet and wall base
    a. Standard Caltech color is Caltech Pure White per Section 09 90 00.
2. Replacement of flooring material with standard flooring material (i.e., carpet or linoleum)
3. Paint ceiling grid or replace damaged ceiling tiles. Do not paint ceiling tiles.
4. New manually controlled window shades and blinds, as deemed necessary
5. Built-in casework:
    a. Reuse existing casework to the extent possible
    b. Casework is typically wood with stain and/or clear finish unless building standard is different, such as Gates-Thomas, which is white laminate bases and clear maple uppers.
6. Office furniture may include sit-stand desks, modular casework, credenza, couches, side or guest chairs, and conference tables located inside the office. Should furniture needs exceed the allowed $20,000 renovation office budget, use of the divisional decentralized reserve is acceptable.
7. New marker boards; typical size is 4’ x 8’, metal enamel
8. New tack boards and chalkboards
9. New room signage outside of the office
10. Minimal electrical work, if not already existing:
    a. Two network outlets
    b. Replace fluorescent lighting with LED, dimmable
    c. Occupancy sensor for light control, new night light controls
    d. Two duplex 120V receptacles at the desk
    e. One 120V receptacle easily accessible for housekeeping
11. For IT, monitor bracket or projector mount only.
    a. Changes should not result in phone and/or data jacks becoming inaccessible (behind furniture or covered by wall treatments).
    b. If data ports are relocated, existing cabling is not to be pulled back to the telecommunications closet and reused. New cat 6A cable (coordinate with IMSS) to be pulled.
12. Services provided by Planning, Design & Construction for management of the renovation and to ensure compliance with building and fire and life safety codes and the Caltech design guidelines

Work excluded in standard new faculty office renovations:

1. Wood or other premium floor material
2. New doors and frames
3. Room function changes that require work to convert a room into an office
4. Wall demolition or new wall construction

5. HVAC, plumbing, or fire protection work
6. Significant ceiling changes beyond paint or limited ceiling tile replacement
7. High-end shades, automatic or powered shades and blinds
8. Abatement of hazardous materials
9. Moves (transportation) costs are managed separately
10. Division provided items—such as monitors, projectors, projector screens, artwork, cameras, speaker systems, ancillary equipment, refrigerators, coffee stations, task chairs, etc.—are not included.
11. Renovations done in older buildings may require work outside of this guideline.

APPENDIX X – PLUMBING PIPING REQUIREMENTS

Caltech Campus Utilities (Plumbing and Mechanical) Table
2026_Campus Centrally Delivered Utilities Specifications Table V5.5

Mechanical Piping Table
2026_Mechanical_Piping_V5.5

Plumbing Fixtures Table
2026_Plumbing_Fixtures_V5.5

Plumbing Piping Table
2026_Plumbing_Piping_V5.5

Mechanical and Plumbing Valve Table
2026_Mechanical_Plumbing_Valves

Steel Pipe pre-cleaning, passivation and corrosion inhibitor charge for closed loop systems

1. Thoroughly flush the system for 2 to 4 hours to remove the heaviest concentration of iron and dirt from the system. After this is done, purge all areas of debris, such as dead ends, remote areas, expansion tank, etc.

   NOTE: Do not bleed out at a rate that exceeds make-up capacity.

   Check pump pressure and water in expansion tank. Ensure drains are not clogged.

2. The system should be pressure washed if possible to lift heavy debris, including loose mill scale and to pressure purge the debris out of the system. The system should be drained a sufficient number of times so that the water appears visually clean of iron, dirt, and assorted other debris. It is vital to flush through all areas of the piping system, heat exchangers, expansion tanks, and dead legs. Verify complete system flushing by comparing loop(s) water conductivity and pH to makeup water conductivity and pH; they should be very similar.

3. Clean all individual strainers, filters, expansion tanks, dead ends, and low flow areas of any debris at each stage of initial cleaning to assure flow.

4. Add 100 ppm of BC 355 (bio-dispersant). Circulate for at least four hours. Add EA 588L (alkaline cleaner). Normal dosage for closed loop system cleaning is 20 pounds per 1000 gallons of water in the system. Circulate this product for 24 to 48 hours.

5. The system should then be flushed under pressure to remove the cleaner and suspended solids. Repeat this process a sufficient number of times to remove all the debris and chemicals. Verify complete system flushing by comparing loop(s) water conductivity and pH to makeup water conductivity and pH. They should be very similar.

6. Clean all individual strainers, filters, expansion tanks, dead ends, and low flow areas of any debris.

7. Check the system for iron, copper and pH. The iron content in the water after cleaning should be lower than 1.0 ppm and the copper content in the water should be lower than 0.2 ppm. Visual appearance of the water should be clear and the pH approximately within 0.2 – 0.3 pH units above the city supply water.

8. After it is determined that the system is thoroughly cleaned, add corrosion inhibitors EA 360 and EA 34TT. Add 22 pounds of EA 360 per 1000 gallons of system water. Add 1.7 pounds of EA 34TT per 1000 gallons of system water. For chilled water systems raise nitrate concentration to at least 500 ppm and an azole residual of at least 2.0 ppm; for hot water systems raise the nitrate concentration to 1000 ppm and keep an azole residual of at least 2.0 ppm.

9. Once the desired nitrate levels are reached, add 100 ppm BC355 to the system for biological control.

Stainless Steel Tubing and Pipe pre-cleaning, passivation procedure for closed loop systems

Step	Product	Dosage	Instructions
Cleaning	Shear 250 (Caustic Soda)	4% (v/v)	Circulate for 1 hour. Maintain temperature at 150º F. Following cleaning, flush with tap water until rinsate pH and conductivity match the makeup pH and conductivity.
Passivation	Acid #14	10% (v/v)	Circulate for 1 hour. Maintain temperature at 120º F. Following Passivation, flush with tap water until rinsate pH and conductivity match the makeup pH and conductivity.

NOTE: No water or chemicals associated with the procedures above shall be discharged to the campus or city sanitary system without full compliance with all applicable codes and regulations and written authorization by Caltech's water treatment supervisor.

Disinfection Procedure for Potable Water Distribution Lines

Summary: This procedure includes all underground and above ground potable water lines for new construction projects and major renovation projects. The intent of the program is to ensure compliance with the methods and procedures outlined in ANSI/AWWA Standard C651-92 and meet the bacteriological standards.

1. Program Description
2. Scope
3. Definitions
4. Responsibilities
5. Specific Program Components
6. Reporting Requirements
7. Information and External References
8. Competency Assessment and Training Requirements

1. Program Description

This procedure was developed to assure potable water lines are properly disinfected and meet the American Water Works Association Standard for community water systems.

2. Scope

This procedure includes all underground and above ground potable water lines for new construction projects and major renovation projects. The intent of the program is to ensure compliance with the methods and procedures outlined in ANSI/AWWA Standard C651-92 and meet the bacteriological standards.

3. Definitions

AWWA: American Water Works Association.

ANSI: American National Standards Institute

ANSI/AWWA Standard C651-92: The current industry practice for the disinfection of underground potable water distribution lines.

Above ground potable water lines: All potable water lines upstream from the water meter.

CFU/ml: Coliform Forming Units per milliliter of water.

Potable Water: Water fit for human consumption.

Sample cock: The end of the distribution line used for water sampling.

Slug Method: Calcium hypochlorite tablets are placed in each section of water lines as the lines are installed.

Potable water lines: All potable water lines downstream from the water meter.

4. Responsibilities

- Contractor is responsible for performing all analytical tests and verifying that the building's plumbing system meets the minimum bacteriological standards as set forth by the California Health and Safety Code.
- Caltech Planning, Design & Construction (PD&C) is responsible for overseeing the entire disinfection procedure including verification of the chlorine residual.

- The general building contractor will provide the personnel, equipment and materials necessary to perform the actual disinfection of the underground lines in compliance with ANSI/AWWA Standard C651-92.
- When a subcontractor performs the disinfection procedure, it is the joint responsibility of both the general contractor and designated subcontractor to comply with this procedure.

5. Specific Program Components

5.1 Underground Potable Water Lines

5.1.1 Standard Disinfection Procedure for all Underground Potable Water Lines

- The forms of chlorine that may be used in the disinfection operations are liquid chlorine, sodium hypochlorite solution, or calcium hypochlorite granules or tablets.
- The Slug method is preferred by Caltech PD&C. NOTE: Caltech PD&C requires the initial Chlorine Residual to be at least 100 ppm (100 mg/L). Tablet or continuous feed methods will require prior approval by Caltech PD&C prior to the installation of the underground piping.
- The Caltech PD&C's inspector will verify the chlorine residual at the end of the retention time and issue a flush order.
- Continuously flush the entire system with clear potable water. The flush water shall be directed into a sanitary sewer system in accordance with Caltech's Storm water Management Plan. Alternative methods of collection of the flush water can be utilized with prior approval from Caltech PD&C.
- Monitor the chlorine residual in the effluent on a periodic basis. When the chlorine residual is equal to the chlorine residual in the distribution system, the system has been properly flushed. Caltech PD&C inspector will contact contractor to arrange for bacteriological testing.

5.1.2 Bacteriological Analysis of the Underground Potable Water Lines

- Contractor will sample the water system effluent from the sample cock. The Total Coliform Count Method, as summarized in "Standard Methods for the Examination of Water and Wastewater" A.P.H.A., will be used to verify the bacteriological water quality.
- When all samples demonstrate that the water system meets the minimum standards, Caltech PD&C will sign off on the disinfection procedure.
- The minimum standards are:
    - Total Coliform Count = Zero.
    - Heterotrophic Plate Count: 500 CFU/ml or less.

5.1.3 Emergency Slug Method

- In cases of emergency when the system must be returned to service as soon as possible, a chlorine residual of 325 ppm with a contact time of only 15 minutes may be used with prior approval from Caltech PD&C. The affected section can be flushed and returned to service if the chlorine residual is not less than 300 ppm when the emergency methods were employed.
- Contractor will sample the system to ensure the water meets minimum bacteriological standards after the system has been placed back into service.

5.2 Above Ground Potable Water Lines

5.2.1 Chlorination Procedure for the Above Ground Potable Water Lines

- PD&C's inspector will verify ALL underground distribution lines (upstream from the meter) have been properly disinfected.
- Thoroughly flush the entire building distribution system with clear potable water. When complete, the contractor will then notify the PD&C's inspector.
- The PD&C inspector will contact contractor to arrange for bacteriological testing of the new system.

5.2.2 Bacteriological Analysis for the Above Ground Potable Water Lines

- Contractor will sample the water system effluent from the sample cock. The Total Coliform Count Method, as summarized in "Standard Methods for the Examination of Water and Wastewater", A.P.H.A. will be used to verify the bacteriological water quality.
- Contractor will also conduct a Heterotrophic Plate Count of water samples from the safety showers and eyewash stations. Ensure the drinking fountains, safety shower and eyewash stations have been thoroughly flushed.
- When all samples demonstrate that the water system meets the minimum standards, Caltech PD&C will sign off on the disinfection procedure.
- The minimum standards are
    - Total Coliform Count = Zero.
    - Heterotrophic Plate Count: 500 CFU/ml or less

6. Reporting Requirements

The general contractor will notify Caltech Planning, Design & Construction department of all scheduled building chlorination procedures at least five days prior to disinfecting the potable water system.

APPENDIX XI – GENERAL MECHANICAL REQUIREMENTS

1. Installation of plumbing and HVAC equipment in an inaccessible manner is prohibited.
   a. All equipment requiring maintenance and replacement shall be located in a readily and conveniently accessible location without the need to remove other fixtures or pieces of equipment.
   b. Such equipment includes and is not limited to fans, motors, cooling coils, heating coils, dampers, actuators, filters, controllers, humidifiers, steam generators, etc.
   c. Installation of equipment shall take into consideration all other building elements such as light fixtures, conduits, room furniture, laboratory equipment, ceiling type, fire sprinklers, plumbing and utility pipes, etc.
   d. All equipment requiring maintenance and replacement shall be located in a readily and conveniently accessible location.
2. Self- performance of TAB by the installing subcontractor is prohibited.
3. Soft soldering plain joints further than 6" from threaded couplings on copper pipes is not allowed.
4. Purge with Nitrogen gas during brazing of all laboratory gases, high purity gases and other utilities. (e.g., vacuum, nitrogen, argon, helium, C02, hydrogen, etc.)
5. Threaded fittings shall be soft soldered using 95/5 soldering compound in order to prevent annealing of the threads.
6. Brazing rods shall contain 15% silver content.
7. Mechanical and plumbing saddle connections on pipes are unacceptable. Use welded, brazed, Threaded TEEs, weldolets, or brazolets instead.
8. Bottom taps or TEEs pointing vertically down on hydronic pipe work are unacceptable. Tap only off the top or side of the pipe.
9. Mechanical pipe joints in concealed spaces. Where installed in shafts and other concealed spaces, Joints shall be brazed or welded.
10. Do not install fiberglass and/or other open-cell type of insulation materials on cold pipes subject to surface condensation.
    a. Installation of only closed cell insulation materials will be acceptable.
11. Installation of Back flow preventers on domestic/potable water pipes.
    a. Backflow preventers are required on Fire water feeds, industrial water, and irrigation water only.
12. Line voltage power feeds into DDC control panels are not acceptable. All components inside a DDC control panel shall be powered from a low voltage transformer that is located outside the DDC panel.
13. Do not utilize 3-point floating TCVs and control schemes in laboratory related applications. Only 0-10 VDC or 4-20 mA control signals are acceptable.
14. Utilization of pumps shall be acceptable only when gravity drainage is not practical or possible.
15. 3-piece ball valves are generally unacceptable.
16. Flexible pipe connections to cooling and heating coils are not acceptable. Hard connect using copper pipe and threaded unions to accommodate de-coupling.
17. Imported pipes, tubing and fittings are generally unacceptable, with the exception of stainless-steel tubing imported from Germany or Japan. All other pipes and tubing shall be manufactured in the USA. (i.e., 100% domestic)
18. Handling and abatement of hazardous materials shall generally be Caltech's responsibility. Caltech project manager and EH&S department shall be involved in assessment of scope and will provide guidance to the project team on how best to deal with Hazardous materials.
19. Hazardous materials abatement shall be the responsibility of Caltech and shall be done prior to the demolition phase. Contact Caltech project manager if abatement is required.
20. Gate valves are not acceptable for any applications, except for steam main shutoff.
21. Soldered valves, strainers, circuit setters, and dielectric unions are not acceptable.
22. No fiberglass lining of ductwork is allowed.
    a. Where lining is required, Armstrong or Rubatex closed cell insulation shall be used.
    b. Duct silencers are preferred over duct lining due to long term maintenance concerns.

23. When providing Equipment Cooling Water supply and return distribution from a water-to-water heat exchanger, such as a Neslab unit, special consideration must be taken to prevent any ECWS&R backflow and subsequent overflow of the unit's reservoir. See Neslab Piping Details for required piping configurations.

24. Laboratory equipment shall never be connected to campus chilled water; a water-to-water heat exchanger shall be utilized.

APPENDIX XII – MECHANICAL AND HVAC HYDRONIC PIPING REQUIREMENTS

Caltech Campus Utilities (Plumbing and Mechanical) Table

2026 Campus Centrally Delivered Utilities Specifications Table V5.5

Mechanical Piping Table

2026_Mechanical_Piping_V5.5

Plumbing Piping Table

2026 Plumbing_Piping V5.5

Mechanical and Plumbing Valve Table

2026 Mechanical_Plumbing_Valves V5.5

APPENDIX XIII – DUCT INSULATION, JACKETING, AND PRESSURE TESTING REQUIREMENTS TABLE

Duct Insulation, Jacketing, and Pressure Testing Table

2026 Duct Insulation Jacketing and Pressure Testing Requirements Table

APPENDIX XIV – CAMPUS UTILITY SHUTDOWN MATRIX

For Caltech Shop Personnel Performing Shutdown

Building name and level (e.g., Braun, Basement	Utility being isolated	Pipe Symbol	Utility Description	Point of disconnect (e.g., near the utility tunnel inside the mechanical room)	Type of isolation valve (e.g., ball, gate, butterfly, plug, globe etc.	Name of person authorizing the shutdown	Isolation Valve holding? (yes / no)
		CHWS and CHWR	Chilled water supply and return				
		HHWS and HHWR	Heating hot water supply and return				
		STM	Steam				
		CS	Clean steam				
		SC	Steam condensate				
		DI / DE	De-ionized or demineralized water				
		RO	Reverse osmosis water				
		HPA	High Pressure Air				
		AIR	Low pressure compressed air				
		DCW	Domestic cold water				
		DHW	Domestic hot water				
		DHWR	Domestic hot water return				

Building name and level (e.g., Braun, Basement	Utility being isolated	Pipe Symbol	Utility Description	Point of disconnect (e.g., near the utility tunnel inside the mechanical room)	Type of isolation valve (e.g., ball, gate, butterfly, plug, globe etc.	Name of person authorizing the shutdown	Isolation Valve holding? (yes / no)
		ICW	Industrial cold water				
		IHW	Industrial hot water				
		IHWR	Industrial hot water return				
		NG	Natural gas				
		VAC	Vacuum				
		N2	Nitrogen				
		CO2	Carbon Dioxide				
		FS	Fire sprinkler				

1) Only Caltech staff are authorized to perform utility shutdowns.

2) Contractor shall request utility shutdowns from the Caltech project manager 5 days prior to required shutdown, in writing.

APPENDIX XV – COMPUTER AIDED DESIGN (CAD) and BUILDING INFORMATION MODELING (BIM) DELIVERABLE STANDARD

1. GENERAL

A. These guidelines will ensure that work produced for the owner will integrate into existing Virtual Design Construction (VDC) files.

B. At the start of the project, a CAD and BIM Deliverable coordination meeting with will be held between Caltech PM, Space Management, and those producing CAD files to review these guidelines and identify any specific concerns. This includes determination of BIM versus 2D requirements, room numbering process, and equipment asset tagging and inventory. The expected authorized use of the BIM model and software versions should also be discussed.

C. CAD files (building plans and base maps) are available for use from theowner

Disclaimer: All CAD files provided by the owner are the "Best Available" at the time of transfer and are for information only. Field verify data as necessary prior to the commencement of any work to ensure accuracy. Floor plan access is intended only for the use by the individual or entity to which it is provided. Any dissemination, distribution, or copying is strictly prohibited without prior written consent from Caltech Planning, Design & Construction.

2. ELECTRONIC DELIVERABLES

2D/3D CAD and BIM MODEL TRANSMISSION: When a large amount of files are to be submitted, use Caltech SharePoint or Box project folder to upload and share files. Caltech PM will share link to SharePoint or Box project folder. Files may not be compressed using ZIP format.

PDF: Deliver all drawing sheets in Portable Document Format (.pdf). Submit one PDF file for each drawing sheet. The PDF document size is to be the same as the full size drawing sheet size. PDFs should be produced from the native program of origin wherever possible.

EXCEL: A drawing index will be supplied in Microsoft Excel Format (.xls). The Excel document will contain separate columns with document attributes as follows: drawing title, revision date, sheet number and discipline. This document will contain all drawings in the "record" set.

MEDIA: Caltech SharePoint or Box project folder to upload and share files. Files may not be compressed using ZIP format.

3. PDF DELIVERABLES

Deliver conformed set of as-built drawing files in Portable Document Format (.pdf). File titles should conform to AIA Page Naming Standards. Page titles should not include any blank spaces.

2D CAD DELIVERABLES FORMAT: Deliver conformed set of as built drawing files in Autodesk's AutoCAD native drawing (.dwg) format. Caltech will accept drawings up to two versions older than the current release version of AutoCAD. Each sheet in the drawing set must be saved as an individual file. File titles should begin with the building number, hyphen, building name, hyphen, floor number, hyphen, discipline, hyphen, followed by other distinguishing information. Drawing titles should not include any blank spaces.

SUPPORT FILES: Deliver all CAD Support files necessary to recreate output that matches hard copy submittals. Support files include, but are not limited to, the following: External References (XRefs), Plot configurations (.ctb, .pc3), blocks, write blocks, images (logos), shapes (.shx) and fonts. Deliver files to the owner free of any copyrighted or other material whose distribution is prohibited.

SUPPORT DOCUMENTATION: Provide support documentation in PDF (.pdf) or Word (.doc) format. Support documentation includes, but is not limited to, the following: List of all layers, layer descriptions, an index matching each CAD file name to the corresponding drawing sheet, and any other special circumstances that warrant further clarification.

LAYERING: Follow Caltech's standard AutoCAD drawing Layer Information (attached) and AIA CAD Layer Guidelines (for anything not mentioned in the Caltech standards). The ability to isolate any set of similar entities must be maintained. Define all entities by layer and not by entity type (e.g. Color and Linetype will be defined as "ByLayer"). Save all drawing files in a 'plot ready state'.

EXTERNAL REFERENCE FILES (XRefs): Each XRef file will have an insertion point of 0, 0, 0; Scale factor of 1; Rotation angle of 0; and reside on a separate layer within the dependent file. In addition, XRef files must be included with each submittal and be located in the same directory as the dependent file. The 'Insert' and 'Bind' options for XRefs will not be accepted.

PAPER SPACE/MODEL SPACE-TABS and PLOTTING LAYOUTS: Each sheet of the drawing set will have one corresponding DWG file. The geometry contained in a file will be in Model Space at full scale. Use Paper Space primarily for setting up the appropriate output size, appearance, border, and title block information. Model Space entities will not be dimensioned or labeled in Paper Space.

MAPPING: Mapping files must align with the Caltech campus map.

4. BIM EXECUTION PLAN

As part of their respective proposals/bid submittals, the architect and the general contract must submit a BIM Execution Plan (BEP) describing processes and procedures in place within their organizations used to coordinate and deliver the BIM's and associated data according to the most recent version of the Caltech design guidelines.

5. 3D BIM/CAD DELIVERABLES

FORMAT: Deliver all drawing files in Autodesk Revit native (.rvt) drawing formats. Caltech will accept drawings two versions older than the current release version of Autodesk Revit. This is in accordance with Autodesk's software retirement program. The version of Autodesk Revit, defined by the design team, and subsequent upgrades should be agreed upon with Caltech.

Fully coordinated architectural, structural, civil and MEP 3D models of existing conditions with Schematic Design (30% set).

Fully coordinated architectural, structural, civil and MEP 3D models in Revit at 100% CD by the Design Team.

Fully coordinated as-built architectural, structural, civil and MEP 3D models in Revit at project close-out.

All equipment schedules must be generated from the parameters embedded in the Revit model objects and tied into Asset Management naming conventions.

SUPPORT FILES: Deliver all assets necessary to recreate output that matches hard copy submittals. Support files include, but are not limited to, the following: AutoCAD native drawing files (.dwg), Images, PDF, excel (.xlsx), and any other External Links. Deliver files to the owner free of any copyrighted or other material whose distribution is prohibited.

LEVEL OF DEVELOPMENT (LOD): Final model deliverables are to be agreed upon with Caltech, and follow the latest AIA Document G202™.

6. GENERAL FILE STANDARDS

COMPONENTS: All models and component families must follow logical grouping and naming conventions.

MODEL VIEWS: Model views must be sorted by floor, prefixed with the corresponding floor level and description, as to display and sort in logical order.

SHEET VIEWS: All sheet views must be prefixed with the corresponding sheet number, logically ordered in a plot-ready state.

7. ROOM TAGS

Design team is mandated to work with Caltech Planning, Design & Construction's space information manager to assign official Caltech room numbers. For projects where there are changes to existing room layouts, design team must consult with Planning and space information manager for any reassignment of room numbers.

Submit floor plans (CAD and pdf) for numbering no later than the end of schematic design so the appropriate Caltech room numbers can be included on all design and construction documents.

All room tags are to be correlated to most current Caltech Asset and Equipment Naming Standards - https://facilitiesoperations.caltech.edu/assetmanagement/namingstandards

8. EQUIPMENT TAGS

All equipment tags are to be correlated to most current Caltech Asset and Equipment Naming Standards - https://facilitiesoperations.caltech.edu/assetmanagement/namingstandards

9. GENERAL DRAWING REQUIRMENTS

SHEET REQUIREMENTS: Drawing sets will have consistent sheet sizes Standard Sheet Size:

Minimum Paper Size: ARCH D (ARCH 4) –24"x36"

Maximum Paper Size (preferred): ARCH E (ARCH 5) – 36"x48"

TITLE BLOCK: The title block will include, but not be limited to, the following information:

Title – Includes building name, building number, floor and room numbers as applicable

Owner's project name

Sheet number

Drawing file name

Revision history – revision number and date

Drawing Phase – BID, CONSTRUCTION, AS-BUILT, etc.

Architect, engineer, consultant, contractor, and/or sub-consultant

10. ACCEPTANCE OF ELECTRONIC DELIVERABLES

Caltech will review electronic file deliverables for compliance with these guidelines prior to acceptance. Files that do not meet these guidelines will require resubmittal.

APPENDIX XVI – UTILITY SHUTDOWN REQUEST FORM

Contractor Requesting Caltech-performed Shutdown

Caltech Project Manager:

Project Name:

Building: Floor(s):

Room Number(s) Affected:

Contractor:

Contractor Contact: Contact Phone:

Preferred Shutdown Date: Time: / Duration:

Contact Signature:

Comment:

Utility being Isola-ted	Pipe Symbol	Utility Description
	CHWS	Chilled water supply
	CHWR	Chilled water return
	DI / DE	De-ionized or demineralized water
	RO	Reverse osmosis water
	DCW	Domestic cold water
	DHW	Domestic hot water
	DHWR	Domestic hot water return
	ICW	Industrial cold water
	IHW	Industrial hot water
	IHWR	Industrial hot water return
	NG	Natural gas
	STM	Steam
	SC	Steam condensate

Utility being Isola-ted	Pipe Symbol	Utility Description
	HHWS	Heating hot water supply and return
	HHWR	Heating hot water return
	DHW	Domestic hot water
	DHWR	Domestic hot water return
	ICW	Industrial cold water
	IHW	Industrial hot water
	IHWR	Industrial hot water return
	NG	Natural gas
	N2	Nitrogen
	CO2	Carbon Dioxide
	FS	Fire sprinkler
	HPA	High Pressure Air
	AIR	Low pressure compressed air
	VAC	Vacuum

1) Only Caltech staff are authorized to perform utility shutdowns.

2) Contractor shall request utility shutdowns from the Caltech PM 5 working days (min.) prior to required shutdown, in writing.

Caltech Approval and Approved Schedule

Caltech Approved Shutdown Date:

Caltech Approved Shutdown Time and Duration:

Comments:

Caltech Person Having Authority Name:

Signature: Date:

Shop Contact Name: Contact Phone:

APPENDIX XVII – BUILDING CONTROLS GUIDE TEMPLATE

"Input Building Name" – Building User Guide

HVAC Systems Overview

The following section describes the basic HVAC systems and provides a more detailed explanation of the sequence of operations.

Please provide an overview of the following items related to the occupied schedule:

1. The locations that the schedule applies to
2. The hours of occupied and unoccupied HVAC function
3. All the setpoints and their corresponding zones
4. Any specific occupied/unoccupied schedule information that the end user will need to know for their space
5. Benefits to the new HVAC system

Please provide an overview of the following items related to the air handler units:

1. Number of air handler units that feed this space
2. The floors and/or spaces that the AHU(s) supply
3. The configuration of the AHU ductwork
4. What controls are in place for the AHU(s)
    a. This can be brief, but should cover the basic controls setup

Please provide an answer to the following questions related to the key controls sequences for the air handler system:

1. What types of supply systems are involved?
    a. Are there cold/hot deck supplies?
        1) Explain how each one interacts with the controls system.
2. Does the system include trim and respond sequencing?
    a. If "yes," explain the concept.
3. How does the system adjust the air flows and temperatures of the spaces?
    a. Provide a brief explanation of how this is accomplished.
    b. Is there a zone request sequence of operations?

1) Explain how the zones work in conjunction with each other to control the air flows and temperatures.

4. Are there overrides for the setpoints?
   a. If “yes,” explain how these are performed.
   b. If “no,” explain why not.
5. Explain any and all setpoint reset integrations for each zone
   a. Window switches?
   b. Static setpoints?
   c. Standby modes?

If applicable, please provide an overview of the following items related to key controls sequences for the heating hot water system:

1. How is the system enabled?
2. Are there overrides?
3. How do the pumps operate?
   a. Lead/lag?
4. Are there any sequences of operations that the end user will need to know?
   a. Describe basic functionality for the HHW system.

Ongoing Monitoring and Fault Detection

If applicable, please provide an overview of the following items related to the location’s monitoring and fault detection system(s):

1. What is the current system in place to perform these duties (i.e., SkySpark)?
   a. Provide an overview of this system.
2. What are the main capabilities of the monitoring system that Caltech has in place?
3. How is this system a benefit to Caltech?

Lighting Controls System Overview

If applicable, please provide an answer to the following questions in an overview of the lighting controls system:

1. Does the new space have a lighting controls system in place that the end user will need to know about?
   a. What areas, zones, or spaces are affected by the new lighting system?
   b. Are there specific space controls for the system?

c. Overrides?

d. Provide the sequence of operations for the new lighting system

e. How does the lighting system operate under normal circumstances?

1) Are there differences when the space is occupied versus unoccupied?

2. How are the new controls a benefit to Caltech?

Lab Specific Controls

If applicable, please provide an answer to the following questions in an overview of the fume hood controls system:

1. Does the new space contain fume hood controls?
2. Where are the new controls installed?
3. How do the new controls operate?
   a. Explain how the end user or users will be affected by the new fume hood controls
4. Are there overrides for the new controls?
5. What is the sequence of operations for these fume hood controls?
6. How are the new controls a benefit to Caltech?

Cold Room Controls

If applicable, please provide an answer to the following questions in an overview of the cold room controls system:

1. Are there specific cold room controls in place?
2. How do they operate in the zone?
3. Are there overrides for the system?
4. How does the end user operate the system?

Animal Facilities

If applicable, please provide an answer to the following questions in an overview of the animal facilities controls system:

1. What controls and monitoring systems are in place to ensure the facility is in compliance with federal regulations and the Guide for the Care and Use of Laboratory Animals?
2. What key controls are in place for the end user?
   a. Are there specific zone controls?

b. What are the setpoints?

3. How does the AHU for these zones function?

   a. Is it a dedicated unit?

   b. Describe the controls system and how it operates to maintain the required temperature

APPENDIX XVIII – General Contractor Safety Guide

https://safety.caltech.edu/documents/16008/Contractor_Safety_Guide.pdf

APPENDIX XIX – CALTECH LANDSCAPE DESIGN PRINCIPLES AND MASTER PLANT LIST

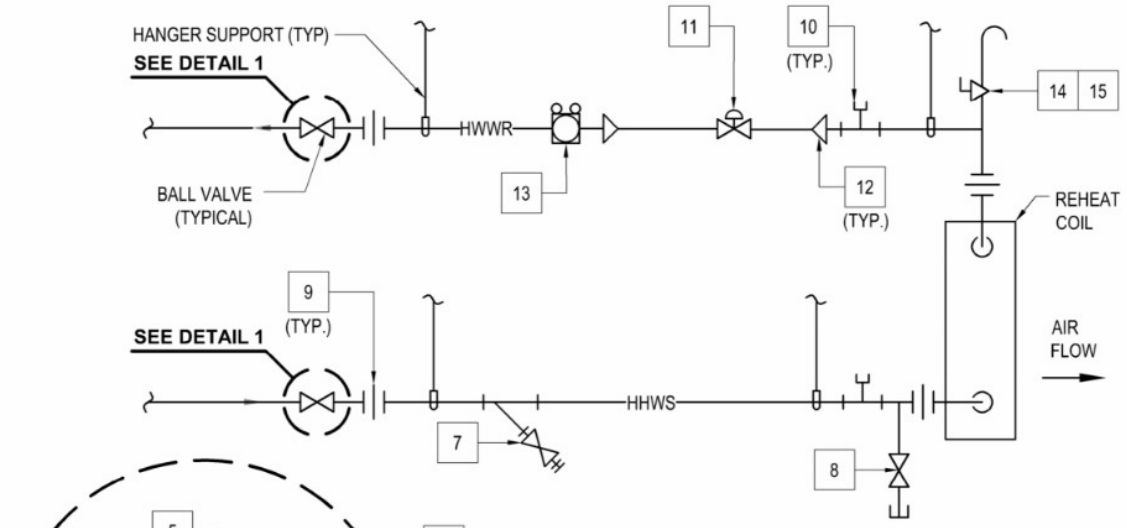
See link: 2024 CALTECH LANDSCAPE DESIGN PRINCIPLES v5.4

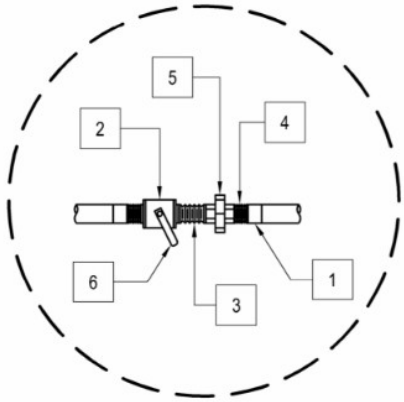
APPENDIX XX – STANDARD DETAILS

List of Standard Details

Detail #	Description
DTL 1	2-Way TCV Reheat Coil Piping Diagram
DTL 2	3-Way TCV Reheat Coil Piping Diagram
DTL 3	AHU Chilled Water Coil Piping Detail (Multiple Coils)
DTL 4	Condensate Drain to Lavatory Sink Tailpiece Connection
DTL 5	Condensate Drain to Laboratory Sink Tailpiece Connection (Acid Waste)
DTL 6	Auto-Sprinkler Drain To A Waste Pipe
DTL 7	Critical Environment Diffuser
DTL 8	Diffuser Connection Detail - (Applicable to Office / Conference Areas)
DTL 9	NOT USED
DTL 10	NOT USED
DTL 11	Round Supply Duct Branch Connection
DTL 12	Round Volume Damper – Larger Than 14” Dia.
DTL 13	NOT USED
DTL 14	NOT USED
DTL 15	Terminal Box Duct Connection Diagram
DTL 16	Typical Diffuser and Exhaust / Return Air Register
DTL 17	NOT USED
DTL 18	NOT USED
DTL 19	NOT USED
DTL 20	Cooling Coil Condensate Trap
DTL 21	Isolation Valve Installation Detail
DTL 22	Steam Piping Connection
DTL 23	End Suction Pump
DTL 24	NOT USED
DTL 25	Fan Coil Unit Cooling Coil
DTL 26	NOT USED
DTL 27	NOT USED

DTL 28	NOT USED
DTL 29	NOT USED
DTL 30	Rectangular Duct Connection
DTL 31	Round Duct Branch Connection
DTL 32	Steam Dirt Leg Trap Assembly
DTL 33	NOT USED
DTL 34	NOT USED
DTL 35	NOT USED
DTL 36	NOT USED
DTL 37	Condensate Return Pump Connection
DTL 38	Nitrogen Mass Flow Meter Piping Diagram
DTL 39	NOT USED
DTL 40	NOT USED
DTL 41	NOT USED
DTL 42	NOT USED
DTL 43	NOT USED
DTL 44	Process Cooling Water Heat Exchanger



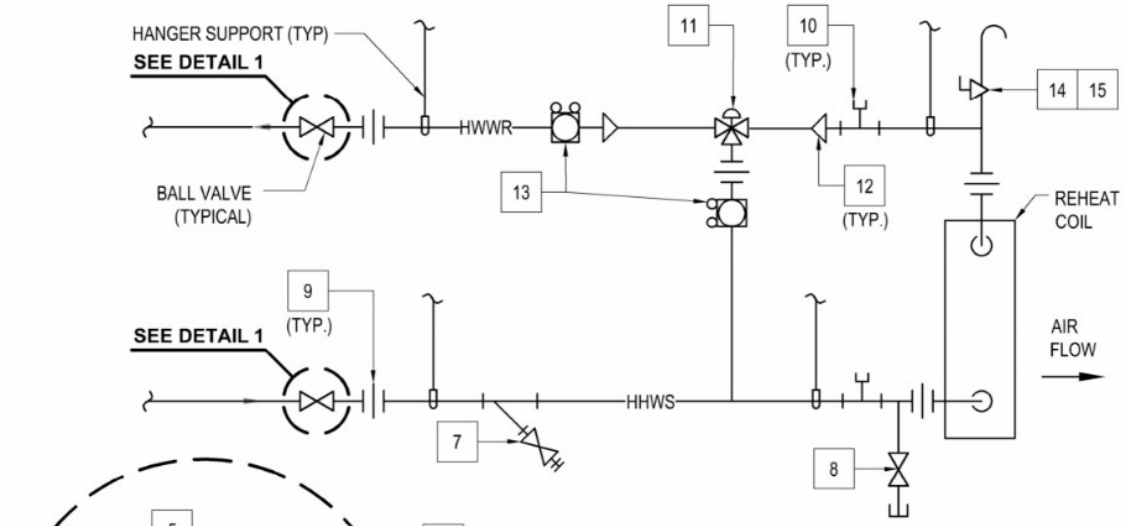


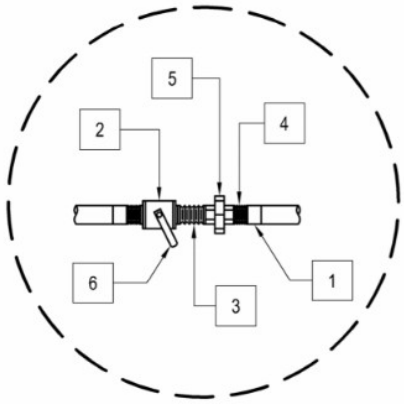
DETAIL 1

1. SOFT-SOLDER OR PROPRESS (BRAZING IS NOT ALLOWED ON THREADED FITTIGNS).
2. ISOLATION BALL VALVE WITH THREADED ENDS, STAINLESS STEEL TRIM VALVE SHALL BE INSTALLED IN AN ACCESSIBLE LOCATION.
   1. **2" & DOWN:** NIBCO T-585-70-66 ------ **2-½" to 3":** APOLLO 77-140 ------ **4":** NIBCO LD-3122-3 ------ **6" & UP:** NIBCO LD-3122-5
3. BRASS OR COPPER NIPPLE (MxM)
4. MALE ADAPTER SOFT-SOLDERED OR PROPRESSED TO PIPE.
5. THREADED UNION (FxF). ISOLATION VALVE INSTALLED ON THE BRANCH SIDE DOWNSTREAM OF THE ISOLATION VALVE.
6. VALVE HANDLE TO BE INSTALLED TO POINT IN THE DIRECTION OF FLOW WHEN IN FULLY OPEN POSITION AND CONVENIENTLY ACCESSIBLE. INSTALL STEM EXTENSIONS ON ALL INSULATED PIPES.
7. Y-STRAINER WITH BALL VALVE & HOSE END CONNECTION:
   1. **2" & DOWN:** WATTS LF777 ------ **2" & UP:** WATTS 77F
8. BLOW-DOWN VALVE W/ HOSE-END FITTING & CAP. DRAIN NEEDED AT LOW POINT, ONLY IF THE STRAINER IS NOT AT THE LOWEST POINT:
   1. **2" & DOWN:** NIBCO T-585-70-66 ------ **2-½" to 3":** APOLLO 77-140 ------ **4":** NIBCO LD-3122-3 ------ **6" & UP:** NIBCO LD-3122-5
9. FIP X FIP BRONZE UNION W/ THREADED ENDS
10. PRESSURE / TEMPERATURE TAPS
    1. PETE'S PLUG 2
11. 2-WAY OR 3-WAY TEMPERATURE CONTROL VALVE BY CONTROLS CONTRACTOR
12. CONCENTRIC REDUCER
13. CIRCUIT BALANCING VALVE
    1. B&G CIRCUIT SETTER
14. MANUAL AIR VENT
    1. B&G MODEL # 4V OR EQUIVALENT
15. AUTOMATIC AIR VENT PIPED W/ SOFT COPPER TUBING TO NEAREST PLUMBING RECEPTOR AS PER PLANS & SPECS
    1. **2" & DOWN:** B&G HOFFMAN SPECIALTY 78 ------ **2" & UP:** B&G 107A

2-Way TCV Reheat Coil Piping Diagram

NOT TO SCALE



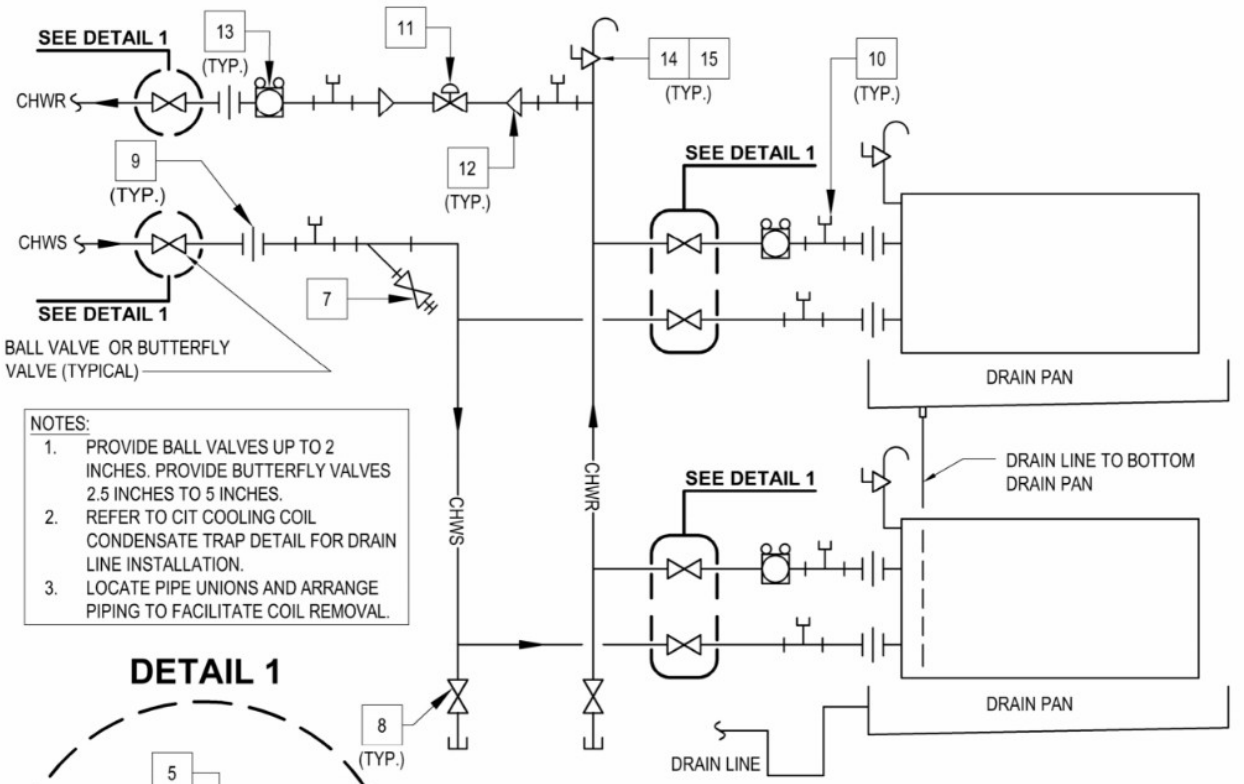


DETAIL 1

1. SOFT-SOLDER OR PROPRESS (BRAZING IS NOT ALLOWED ON THREADED FITTIGNS).
2. ISOLATION BALL VALVE WITH THREADED ENDS, STAINLESS STEEL TRIM VALVE SHALL BE INSTALLED IN AN ACCESSIBLE LOCATION.
   1. **2" & DOWN:** NIBCO T-585-70-66 ------ **2-½" to 3":** APOLLO 77-140 ------ **4":** NIBCO LD-3122-3 ------ **6" & UP:** NIBCO LD-3122-5
3. BRASS OR COPPER NIPPLE (MxM)
4. MALE ADAPTER SOFT-SOLDERED OR PROPRESSED TO PIPE.
5. THREADED UNION (FxF). ISOLATION VALVE INSTALLED ON THE BRANCH SIDE DOWNSTREAM OF THE ISOLATION VALVE.
6. VALVE HANDLE TO BE INSTALLED TO POINT IN THE DIRECTION OF FLOW WHEN IN FULLY OPEN POSITION AND CONVENIENTLY ACCESSIBLE. INSTALL STEM EXTENSIONS ON ALL INSULATED PIPES.
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   1. **2" & DOWN:** WATTS LF777 ------ **2" & UP:** WATTS 77F
8. BLOW-DOWN VALVE W/ HOSE-END FITTING & CAP. DRAIN NEEDED AT LOW POINT, ONLY IF THE STRAINER IS NOT AT THE LOWEST POINT:
   1. **2" & DOWN:** NIBCO T-585-70-66 ------ **2-½" to 3":** APOLLO 77-140 ------ **4":** NIBCO LD-3122-3 ------ **6" & UP:** NIBCO LD-3122-5
9. FIP X FIP BRONZE UNION W/ THREADED ENDS
10. PRESSURE / TEMPERATURE TAPS
    1. PETE'S PLUG 2
11. 2-WAY OR 3-WAY TEMPERATURE CONTROL VALVE BY CONTROLS CONTRACTOR
12. CONCENTRIC REDUCER
13. CIRCUIT BALANCING VALVE
    1. B&G CIRCUIT SETTER
14. MANUAL AIR VENT
    1. B&G MODEL # 4V OR EQUIVALENT
15. AUTOMATIC AIR VENT PIPED W/ SOFT COPPER TUBING TO NEAREST PLUMBING RECEPTOR AS PER PLANS & SPECS
    1. **2" & DOWN:** B&G HOFFMAN SPECIALTY 78 ------ **2" & UP:** B&G 107A

3-Way TCV Reheat Coil Piping Diagram

NOT TO SCALE



1 SOFT-SOLDER OR PROPRESS (BRAZING IS NOT ALLOWED ON THREADED FITTIGNS).

2 ISOLATION BALL VALVE WITH THREADED ENDS, STAINLESS STEEL TRIM VALVE SHALL BE INSTALLED IN AN ACCESSIBLE LOCATION.
1. **2" & DOWN:** NIBCO T-585-70-66 ------ **2-½" to 3":** APOLLO 77-140 ------ **4":** NIBCO LD-3122-3 ------ **6" & UP:** NIBCO LD-3122-5

3 BRASS OR COPPER NIPPLE (MxM)

4 MALE ADAPTER SOLT-SOLDERED OR PROPRESSED TO PIPE.

5 THREADED UNION (FxF). ISOLATION VALVE INSTALLED ON THE BRANCH SIDE DOWNSTREAM OF THE ISOLATION VALVE.

6 VALVE HANDLE TO BE INSTALLED TO POINT IN THE DIRECTION OF FLOW WHEN IN FULLY OPEN POSITION AND CONVENIENTLY ACCESSIBLE. INSTALL STEM EXTENSIONS ON ALL INSULATED PIPES.

7 Y-STRAINER WITH BALL VALVE & HOSE END CONNECTION:
1. **2" & DOWN:** WATTS LF777 ------ **2" & UP:** WATTS 77F

8 BLOW-DOWN VALVE W/ HOSE-END FITTING & CAP. DRAIN NEEDED AT LOW POINT, ONLY IF THE STRAINER IS NOT AT THE LOWEST POINT:
1. **2" & DOWN:** NIBCO T-585-70-66 ------ **2-½" to 3":** APOLLO 77-140 ------ **4":** NIBCO LD-3122-3 ------ **6" & UP:** NIBCO LD-3122-5

9 FIP X FIP BRONZE UNION W/ THREADED ENDS

10 PRESSURE / TEMPERATURE TAPS
1. PETE'S PLUG 2

11 2-WAY OR 3-WAY TEMPERATURE CONTROL VALVE BY CONTROLS CONTRACTOR

12 CONCENTRIC REDUCER

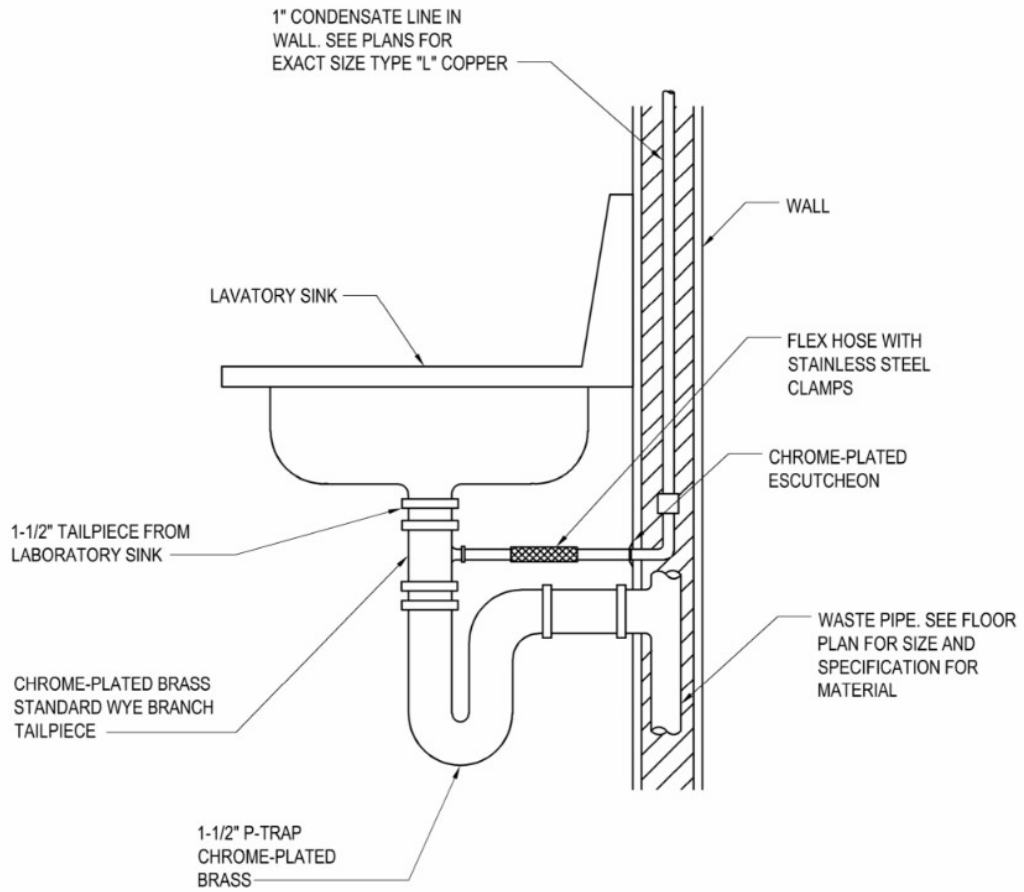
13 CIRCUIT BALANCING VALVE
1. B&G CIRCUIT SETTER

14 MANUAL AIR VENT
1. B&G MODEL # 4V OR EQUIVALENT

15 AUTOMATIC AIR VENT PIPED W/ SOFT COPPER TUBING TO NEAREST PLUMBING RECEPTOR AS PER PLANS & SPECS
1. **2" & DOWN:** B&G HOFFMAN SPECIALTY 78 ------ **2" & UP:** B&G 107A

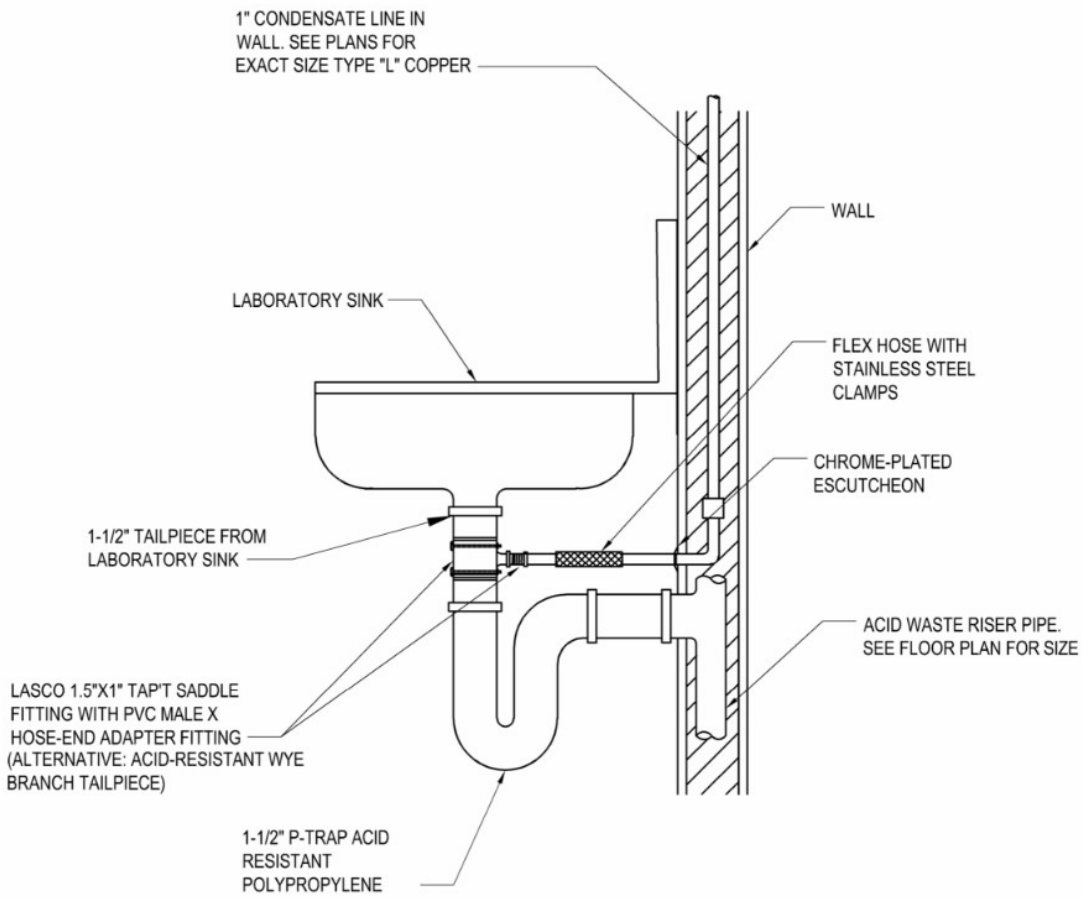
AHU CHILLED WATER COIL PIPING DETAIL (MULTIPLE COILS)

NOT TO SCALE



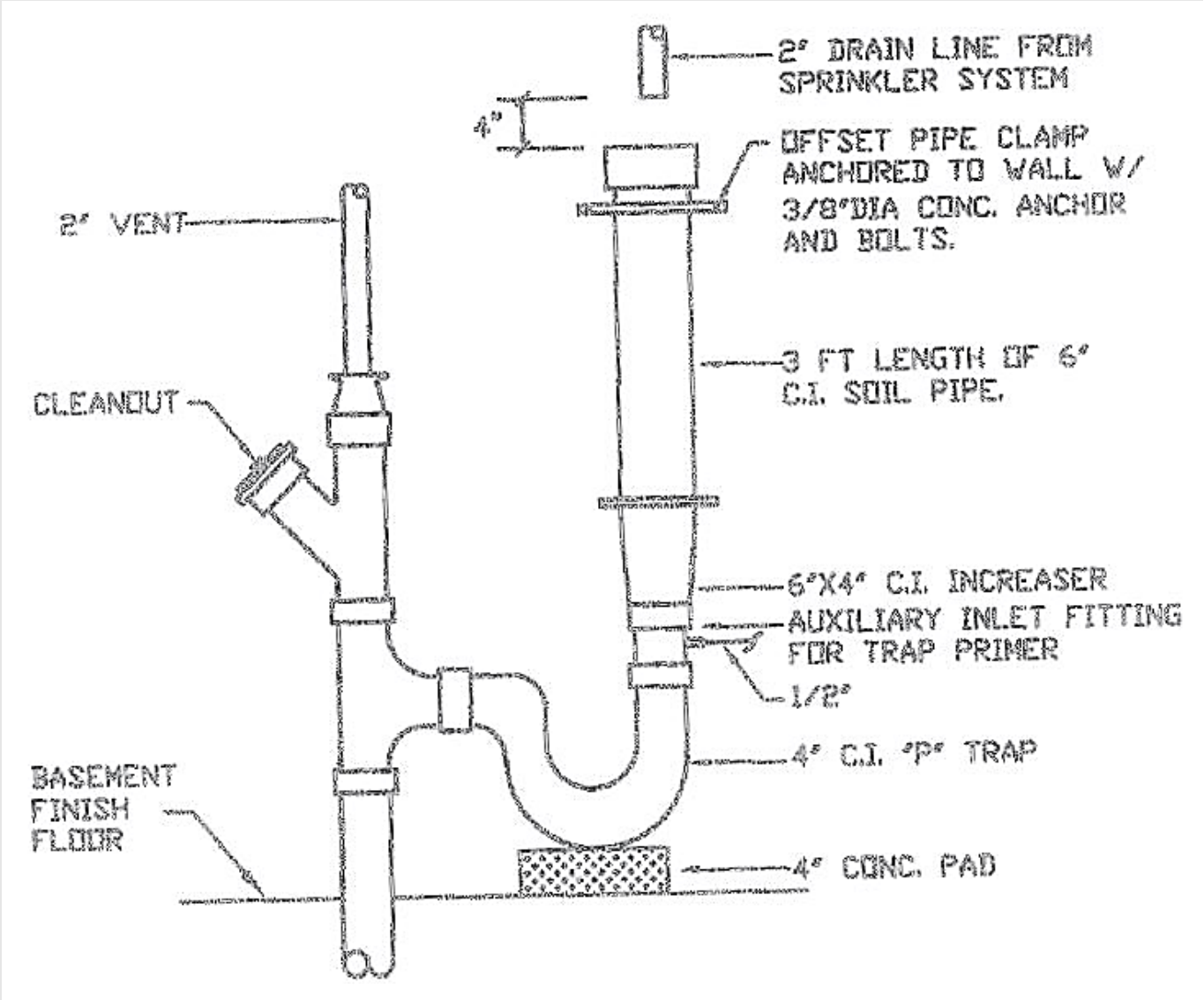
CONDENSATE DRAIN TO LABORATORY SINK TAILPIECE CONNECTION

NOT TO SCALE



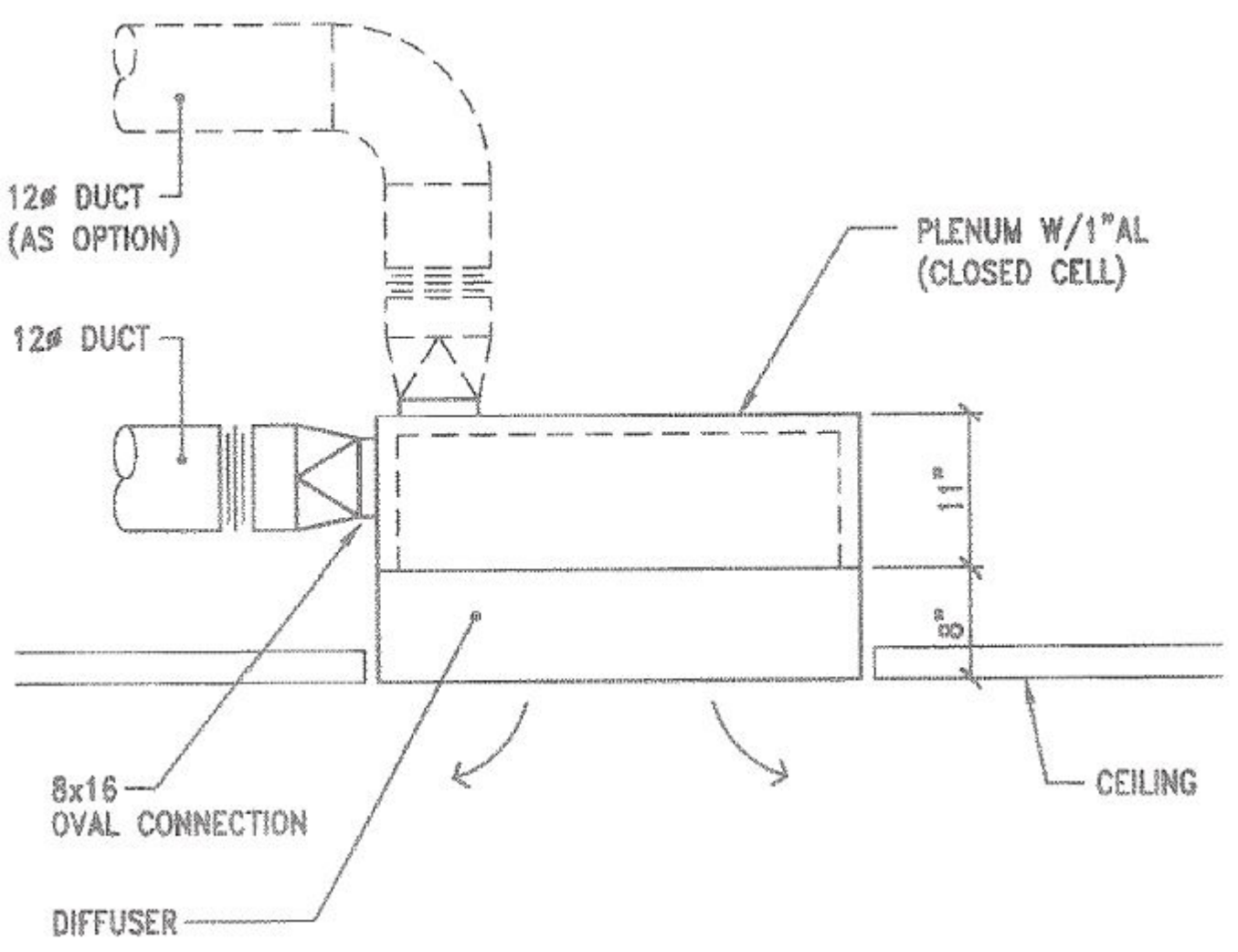
CONDENSATE DRAIN TO LABORATORY SINK TAILPIECE CONNECTION (ACID WASTE)

NOT TO SCALE



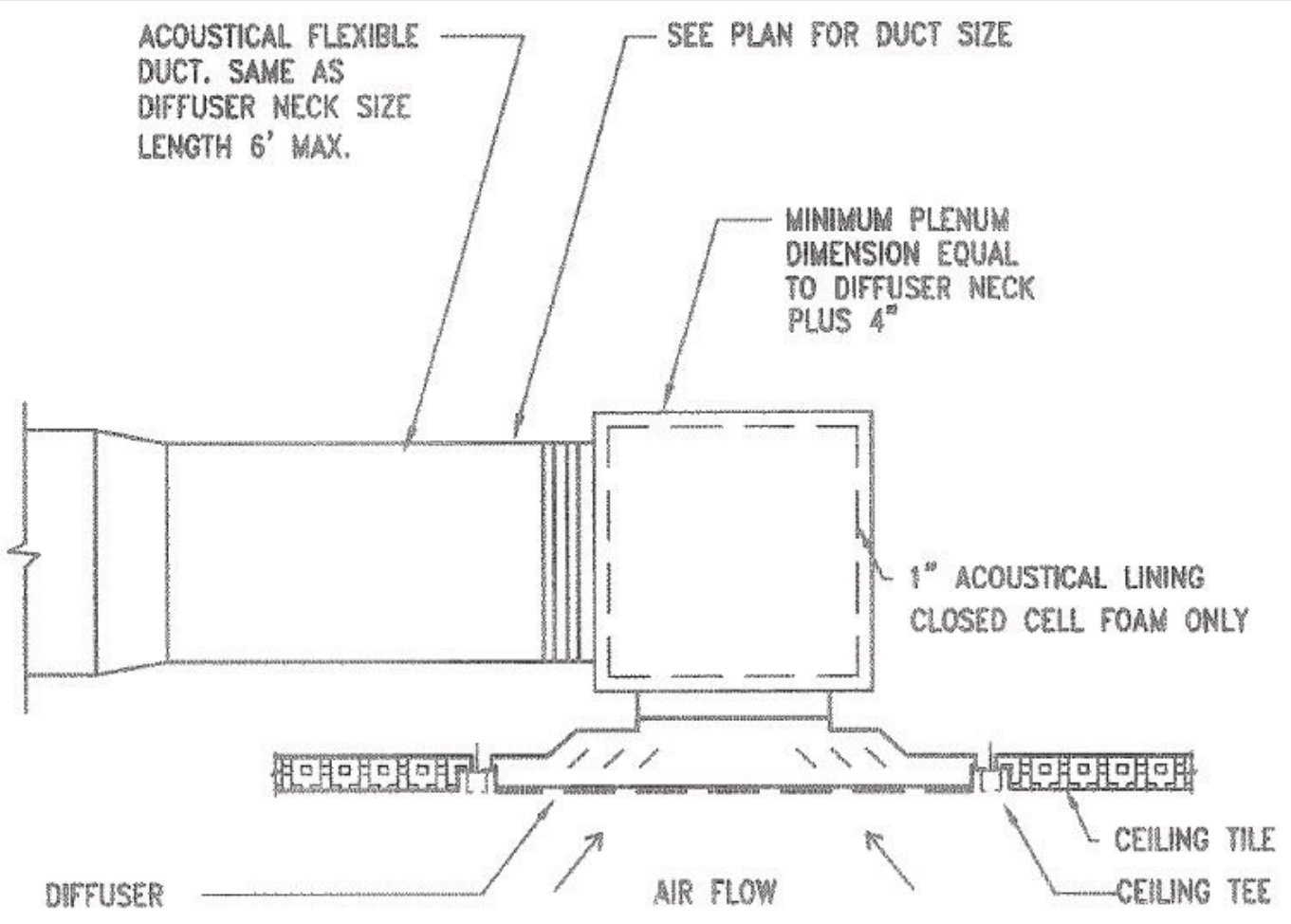
Auto-Sprinkler Drain To A Waste Pipe

Keywords: Cleanout, Increaser, Trap Primer, Soil Pipe, Drain, Sprinkler System, Pipe Clamp, Concrete Anchor



Critical Environment Diffuser

Keywords: Duct, Plenum, Ceiling, Closed Cell, Connection, Diffuser

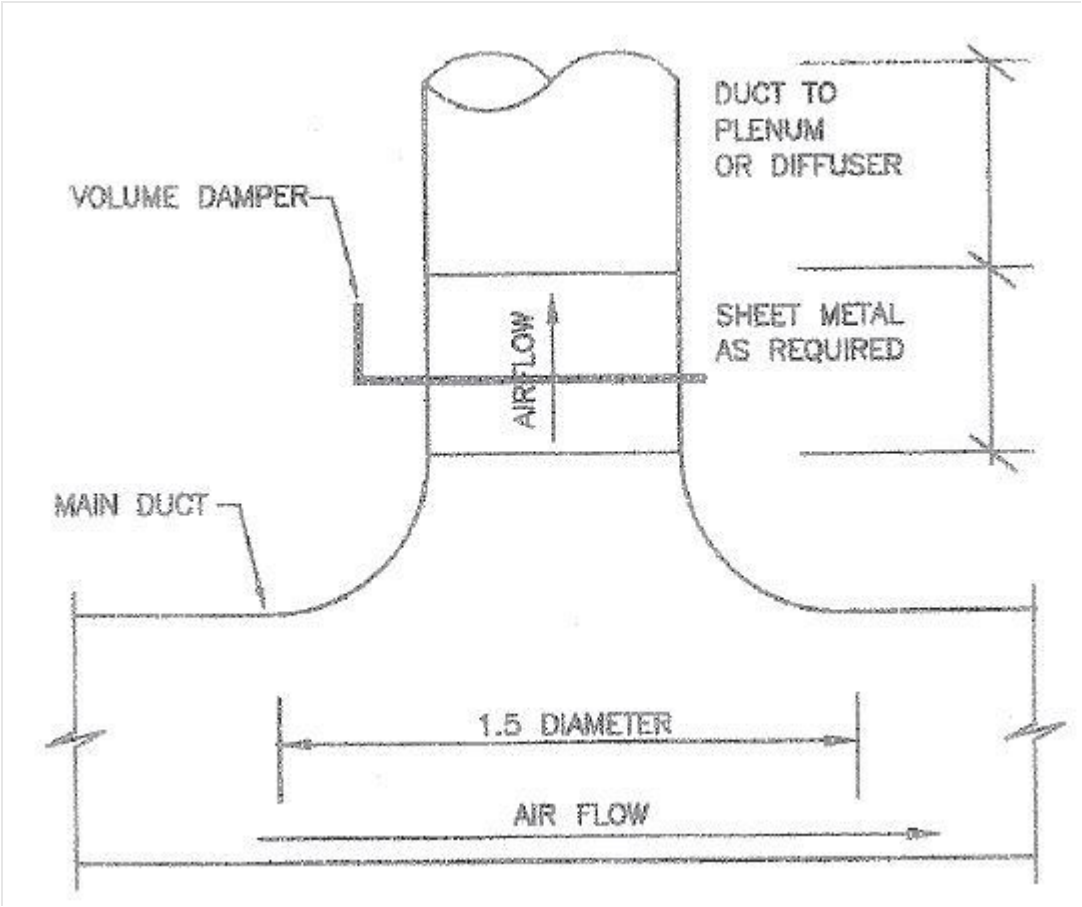


NOTE: Provide Acoustical Lining for all Branch Ductwork beyond Terminal Units and Diffusers in Office and Conference Areas.

Diffuser Connection Detail

(Applicable to Office / Conference Areas)

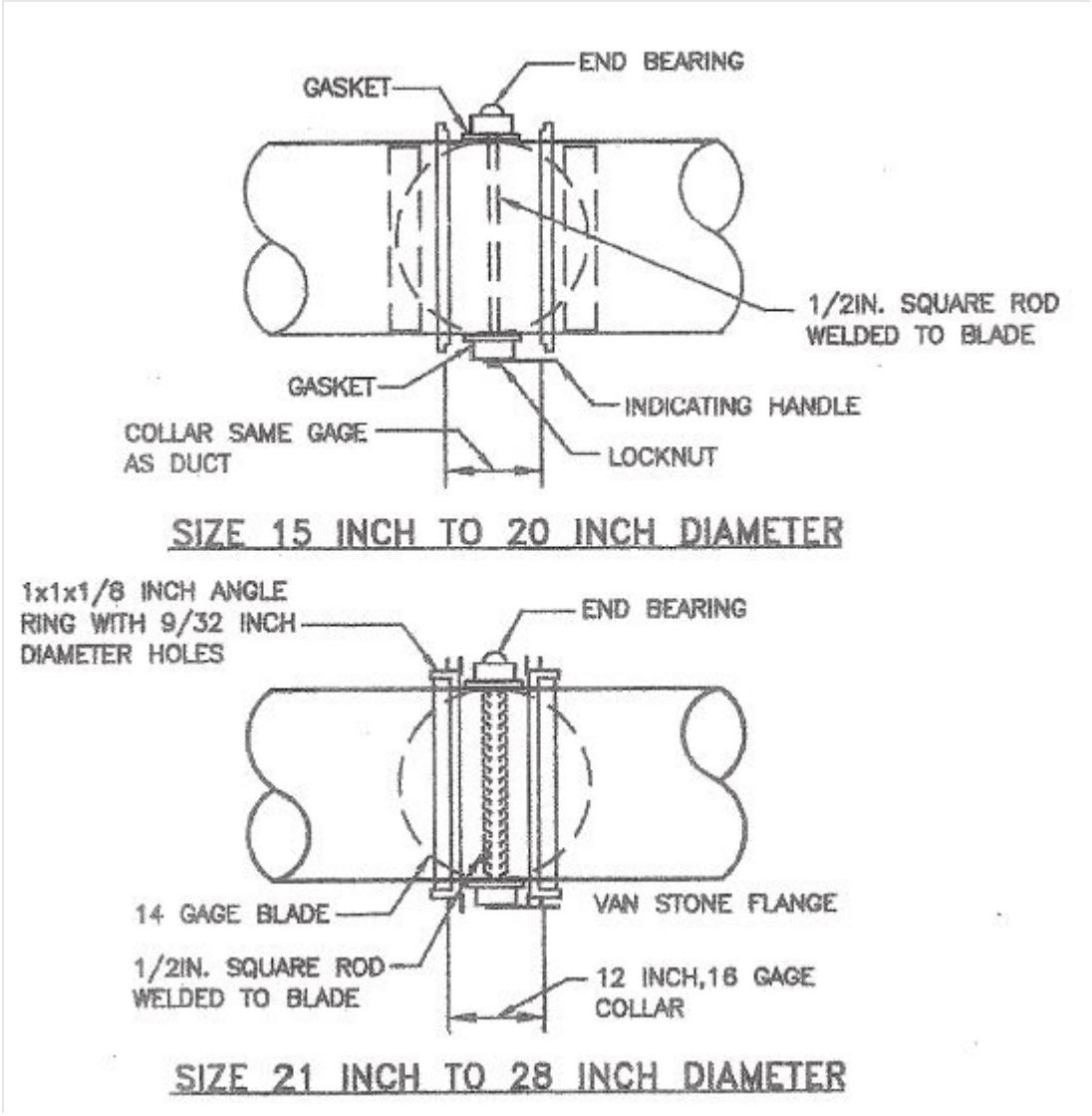
Keywords: Duct, Ceiling Tile, Closed Cell, Diffuser, Air Flow, Acoustical, Flexible, Plenum



NOTE: Furnish This Type Connection When Single-Line Ductwork is indicated as this for Branches with More Than 25% of Total Air Flow

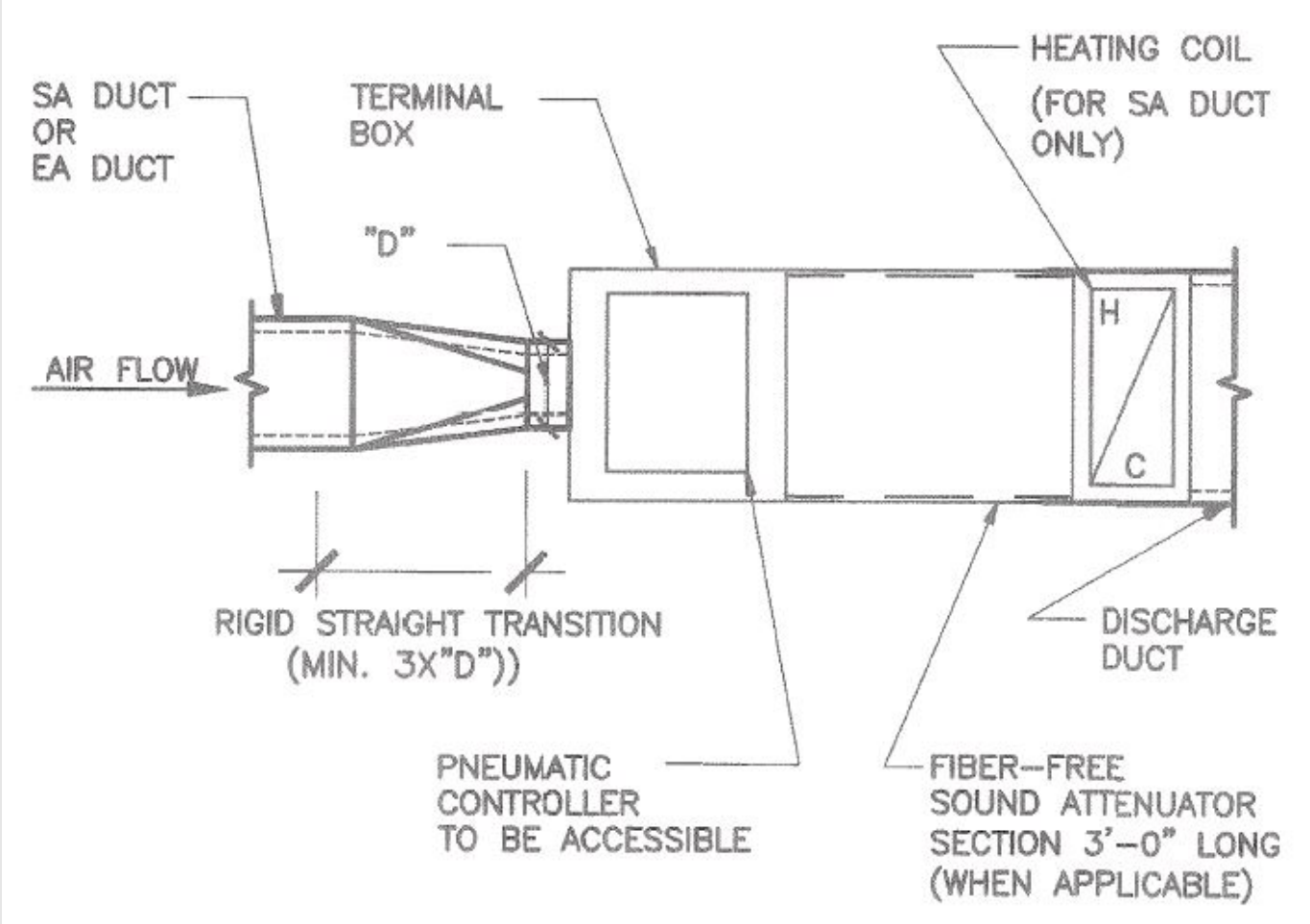
Round Supply Duct Branch Connection

Keywords: Damper, Plenum, Diffuser, Sheet Metal, Duct



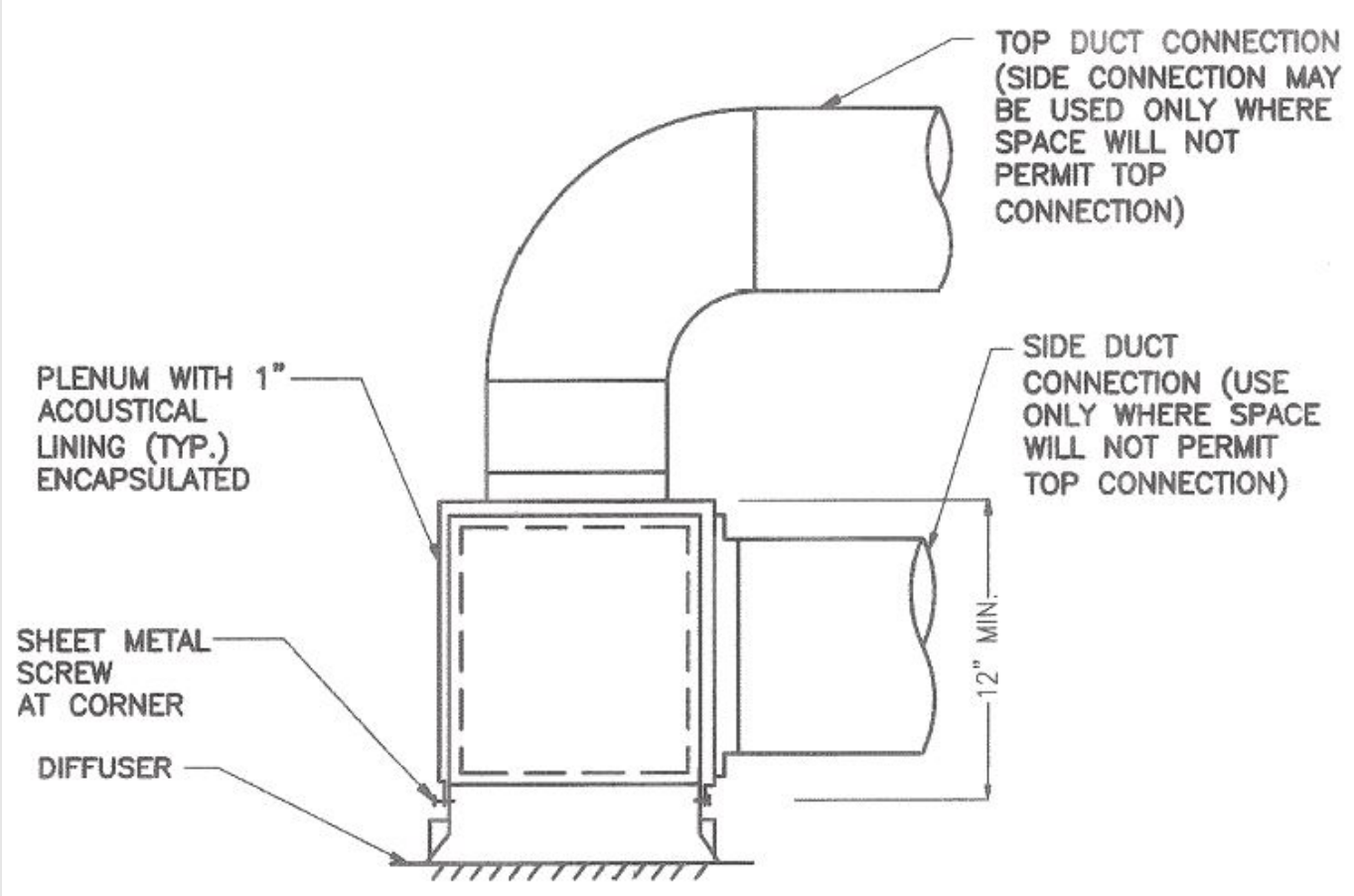
Round Volume Damper – Larger Than 14” Dia.

Keywords: Damper, Duct, Collar, Gasket, Bearing, Rod, Handle, Locknut, Blade, Van Stone Flange



Terminal Box Duct Connection Diagram

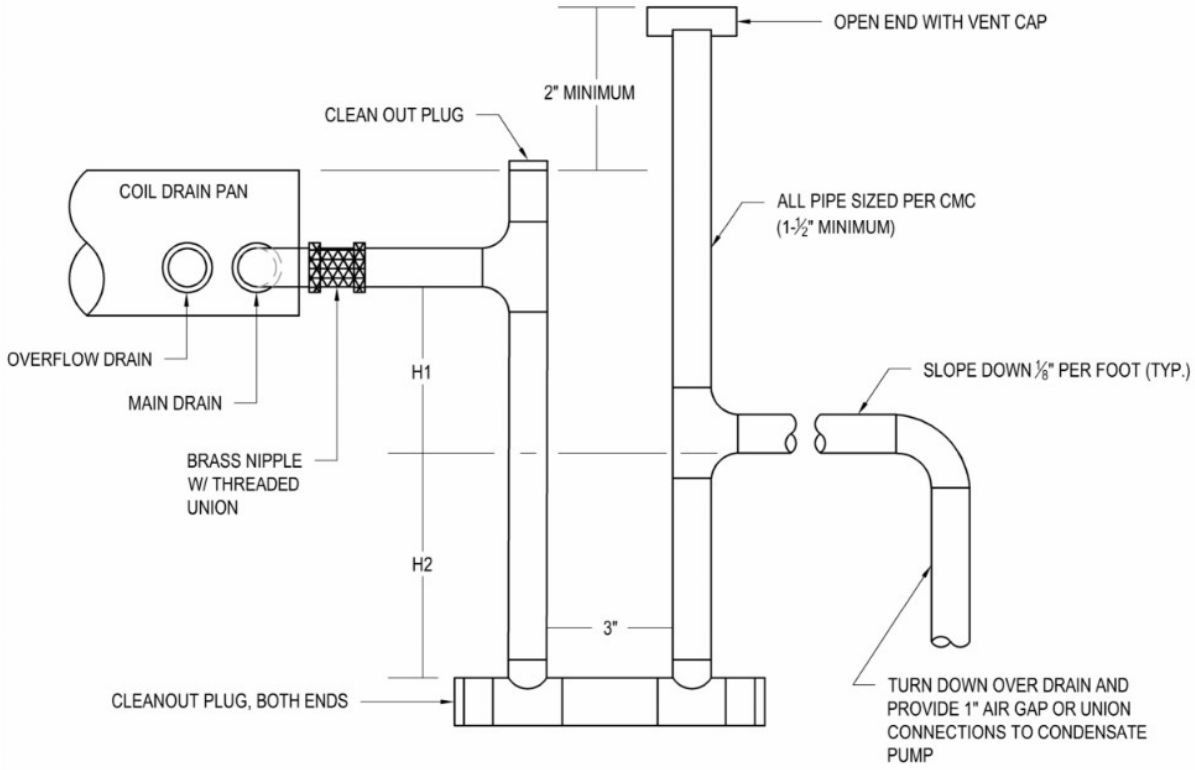
Keywords: Duct, Terminal Box, Heating Coil, Discharge, Transition, Pneumatic Controller, Sound Attenuator



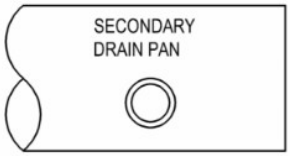
Typical Diffuser and Exhaust / Return Air Register

Keywords: Duct, Plenum, Sheet Metal, Connection

COIL TYPE	H1 (HEIGHT)	H2 (HEIGHT)
BLOW-THROUGH (LOCATED ON DISCHARGE SIDE OF FAN)	1" MINIMUM	POSITIVE STATIC PRESSURE AT DRAIN PAN IN INCHES TIMES 2 (2 INCHES MINIMUM)
DRAW-THROUGH (LOCATED ON SUCTION SIDE OF FAN)	NEGATIVE STATIC PRESSURE AT DRAIN PAN IN INCHES PLUS 1 INCH	NEGATIVE STATIC PRESSURE AT DRAIN PAN IN INCHES PLUS 1 INCH



NOTE: WHEN AN AIR HANDLER IS LOCATED ABOVE A FINISHED SPACE, THE SECONDARY DRAIN PAN MUST HAVE A LARGER FOOTPRINT THAN THE AIR HANDLER.



WHEN A COIL IS LOCATED ABOVE A FINISHED SPACE, A 1" MINIMUM SECONDARY DRAIN LINE SHALL BE:

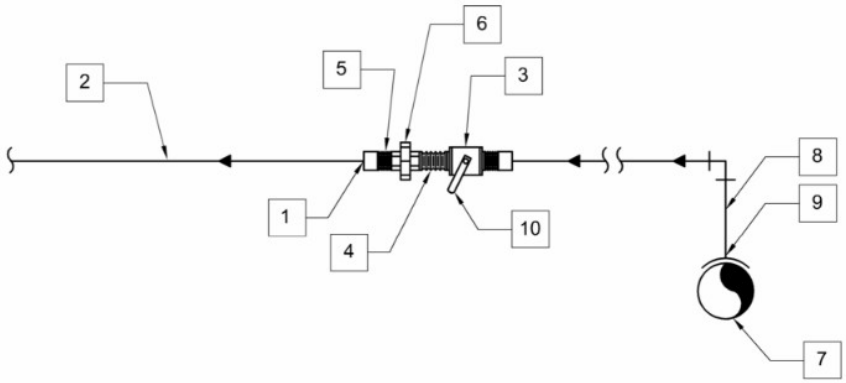
CONNECTED TO SECONDARY DRAIN PAN OR CONNECTED TO THE OVERFLOW DRAIN OUTLET OF THE AIR HANDLER DRAIN PAN

OVERFLOW DRAIN LINE
ALWAYS RUN AN OVERFLOW DRAIN LINE, IF NOT POSSIBLE TO ROUTE OVERFLOW DRAIN LINE, INSTALL OVERFLOW SWITCH AND WIRE TO DEGENERIZE UNIT UPON DETECTION OF CONDENSATE

COOLING COIL CONDENSATE TRAP

NOT TO SCALE

KEYWORDS: BRASS, UNION, COOLING COIL, CLEAN OUT, PLUG, AIR GAP, CONDENSATE PUMP, SLOPE, VENT CAP

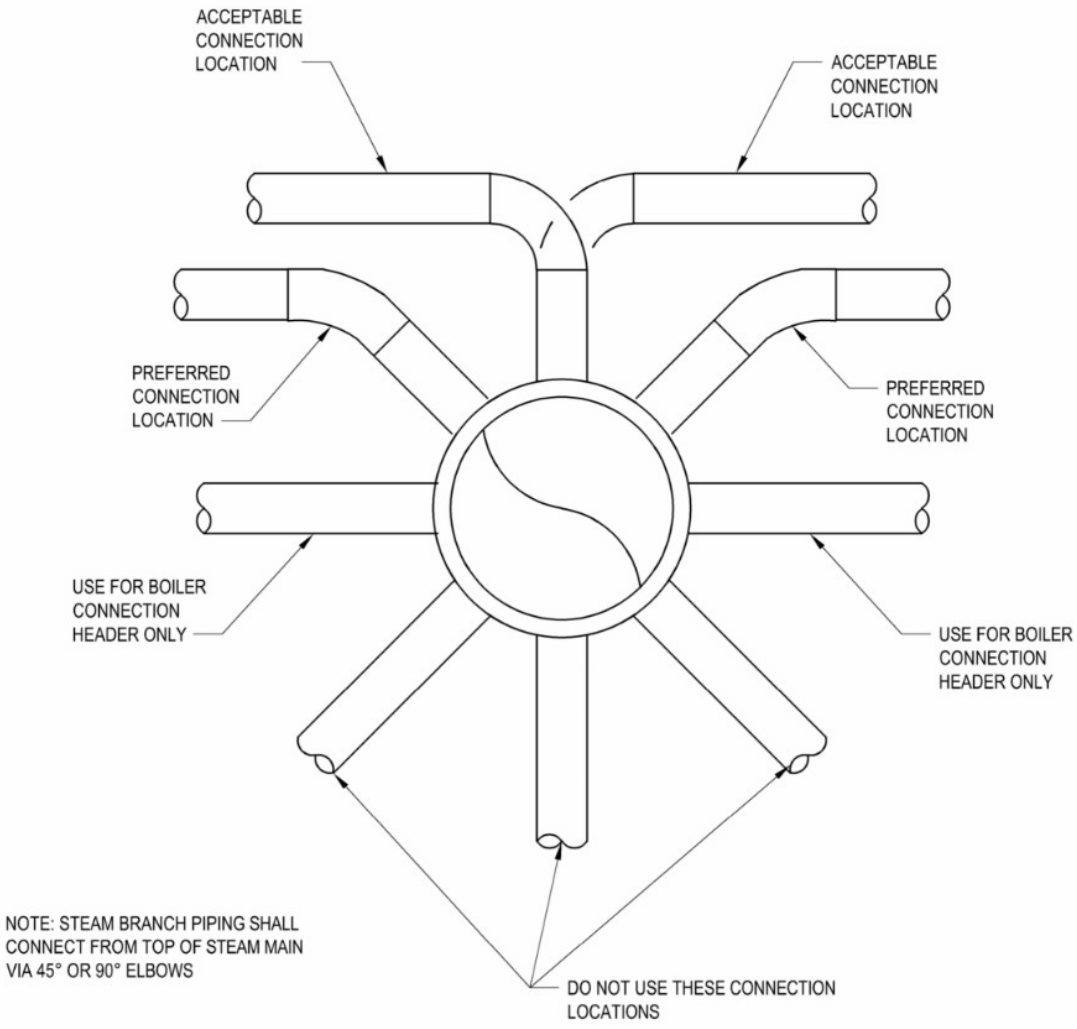


KEYNOTES:

1. SOFT-SOLDER OR PROPRESS (BRAZING IS NOT ALLOWED ON THREADED FITTINGS).
2. TYPE "L" COPPER PIPE.
3. ISOLATION BALL VALVE WITH THREADED ENDS, STAINLESS STEEL TRIM VALVE SHALL BE INSTALLED IN AN ACCESSIBLE LOCATION.
4. BRASS OR COPPER NIPPLE (MxM).
5. MALE ADAPTER SOFT-SOLDERED OR PROPRESSED TO PIPE.
6. THREADED UNION (FxF). ISOLATION VALVE INSTALLED ON THE BRANCH SIDE DOWNSTREAM OF THE ISOLATION VALVE.
7. MAIN OR BRANCH MAIN PIPE.
8. TOP-TAP OR SIDE-TAPPED BRANCH PIPE.
9. BRANCH PIPE TO MAIN PIPE POC. (BRAZOLET OR TEE FITTING).
10. VALVE HANDLE TO BE INSTALLED TO POINT IN THE DIRECTION OF FLOW WHEN IN FULLY OPEN POSITION AND CONVENIENTLY ACCESSIBLE. INSTALL STEM EXTENSIONS ON ALL INSULATED PIPES.

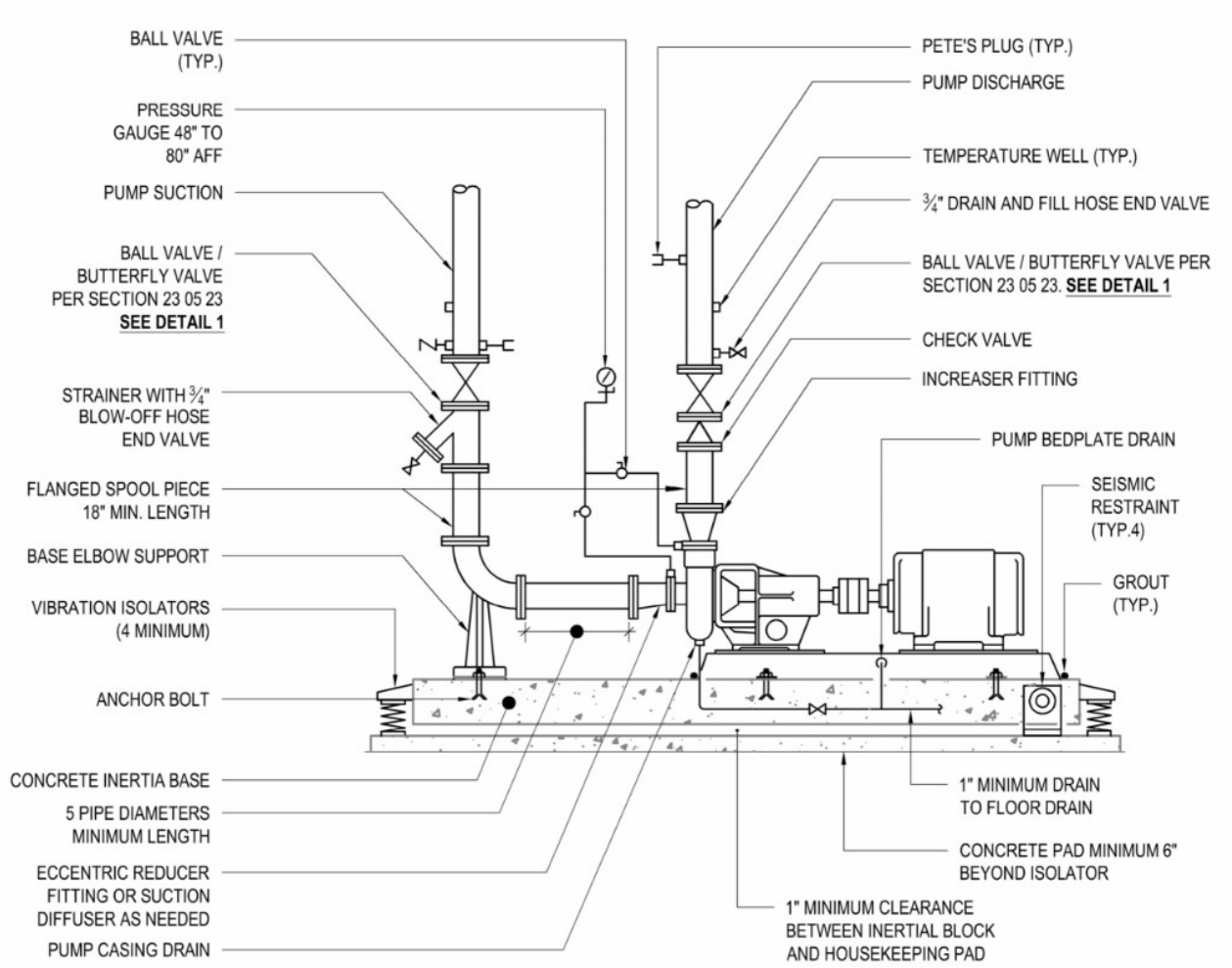
ISOLATION VALVE INSTALLATION DETAIL

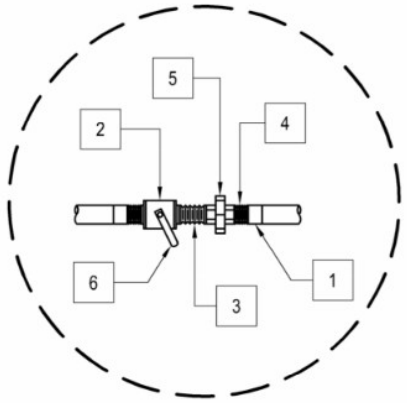
NOT TO SCALE



STEAM PIPING CONNECTIONS

NOT TO SCALE



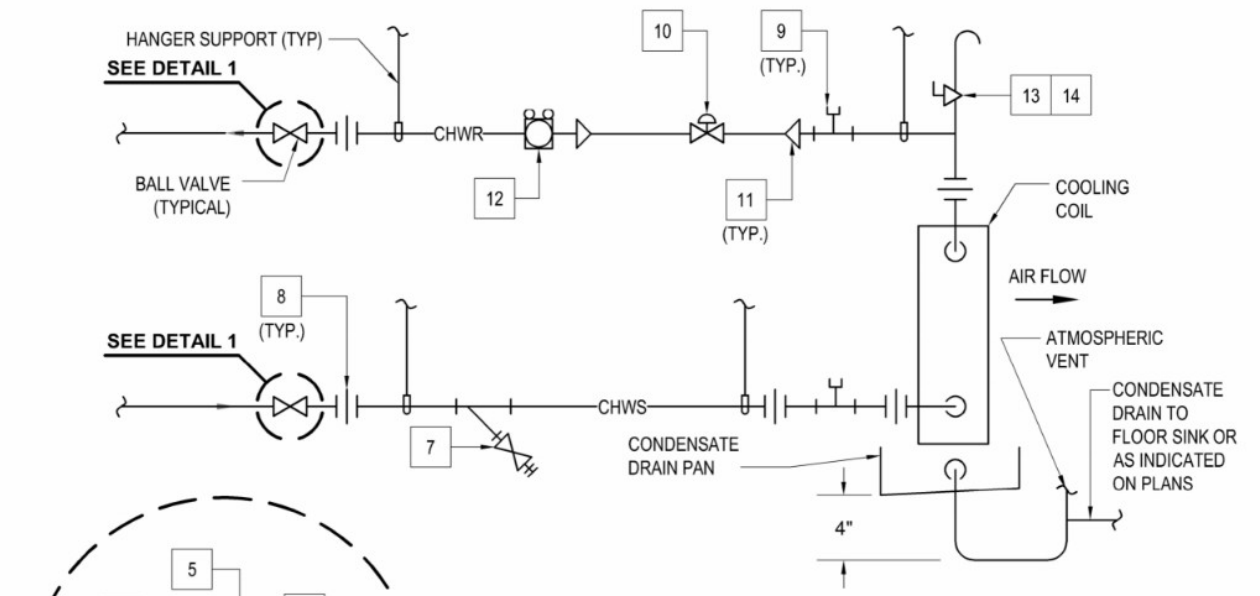


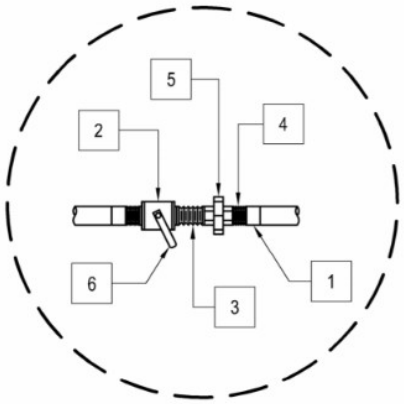
DETAIL 1

1. SOFT-SOLDER OR PROPRESS (BRAZING IS NOT ALLOWED ON THREADED FITTIGNS).
2. ISOLATION BALL VALVE WITH THREADED ENDS, STAINLESS STEEL TRIM VALVE SHALL BE INSTALLED IN AN ACCESSIBLE LOCATION.
   1. **2" & DOWN:** NIBCO T-585-70-66 ------ **2-½" to 3":** APOLLO 77-140 ------ **4":** NIBCO LD-3122-3 ------ **6" & UP:** NIBCO LD-3122-5
3. BRASS OR COPPER NIPPLE (MxM)
4. MALE ADAPTER SOFT-SOLDERED OR PROPRESSED TO PIPE.
5. THREADED UNION (FxF). ISOLATION VALVE INSTALLED ON THE BRANCH SIDE DOWNSTREAM OF THE ISOLATION VALVE.
6. VALVE HANDLE TO BE INSTALLED TO POINT IN THE DIRECTION OF FLOW WHEN IN FULLY OPEN POSITION AND CONVENIENTLY ACCESSIBLE. INSTALL STEM EXTENSIONS ON ALL INSULATED PIPES.

END SUCTION PUMP

NOT TO SCALE





DETAIL 1

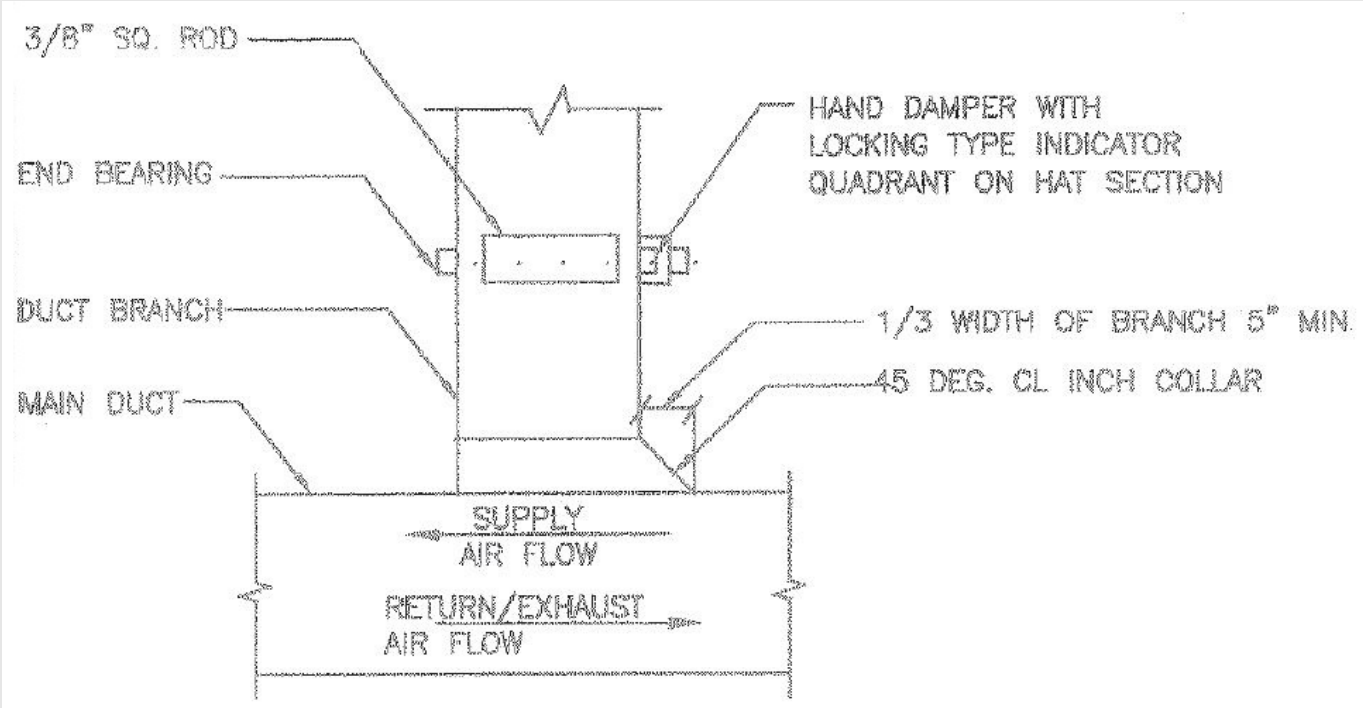
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7. Y-STRAINER WITH BALL VALVE & HOSE END CONNECTION:
   1. **2" & DOWN:** WATTS LF777 ------ **2" & UP:** WATTS 77F
8. FIP X FIP BRONZE UNION W/ THREADED ENDS
9. PRESSURE / TEMPERATURE TAPS
   1. PETE'S PLUG 2
10. 2-WAY OR 3-WAY TEMPERATURE CONTROL VALVE BY CONTROLS CONTRACTOR
11. CONCENTRIC REDUCER
12. CIRCUIT BALANCING VALVE
    1. B&G CIRCUIT SETTER
13. MANUAL AIR VENT
    1. B&G MODEL # 4V OR EQUIVALENT
14. AUTOMATIC AIR VENT PIPED W/ SOFT COPPER TUBING TO NEAREST PLUMBING RECEPTOR AS PER PLANS & SPECS
    1. **2" & DOWN:** B&G HOFFMAN SPECIALTY 78 ------ **2" & UP:** B&G 107A

NOTES:

1. THIS DETAIL ALSO APPLIES TO PROCESS COOLING EQUIPMENT (EG. AUTOCLAVES, WATER-COOLED COLD ROOM CONDENSING UNITS, FERMENTERS, BIO-REACTORS, ETC).

FAN COIL UNIT COOLING COIL

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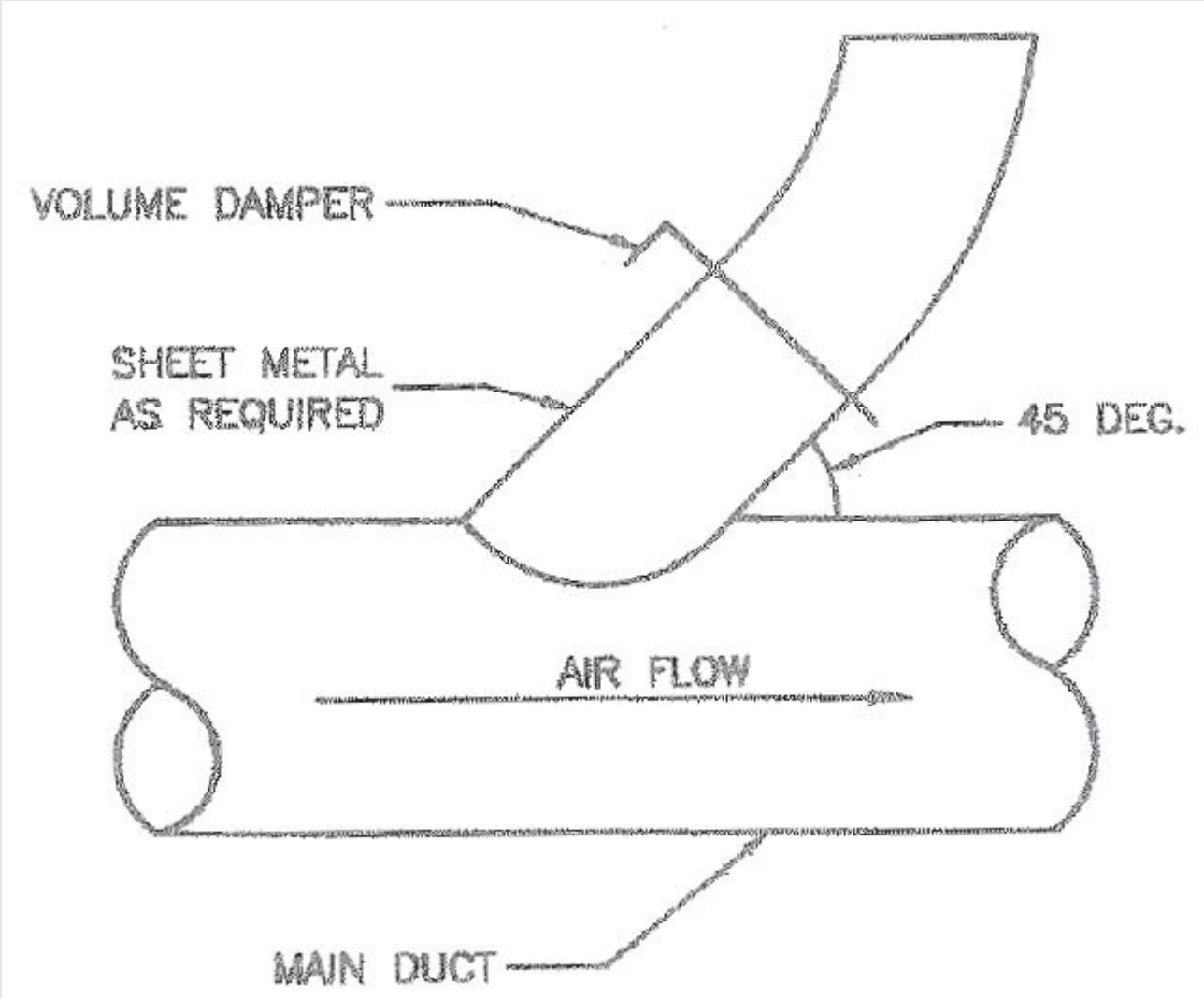


NOTES:

Furnish this type connection when single-line ductwork is indicated as this for branches with less than 25% of the total air flow

Rectangular Duct Connection

Keywords: End Bearing, Main Duct, Duct Branch, Collar, Damper, Indicator, Quadrant, Hat Section

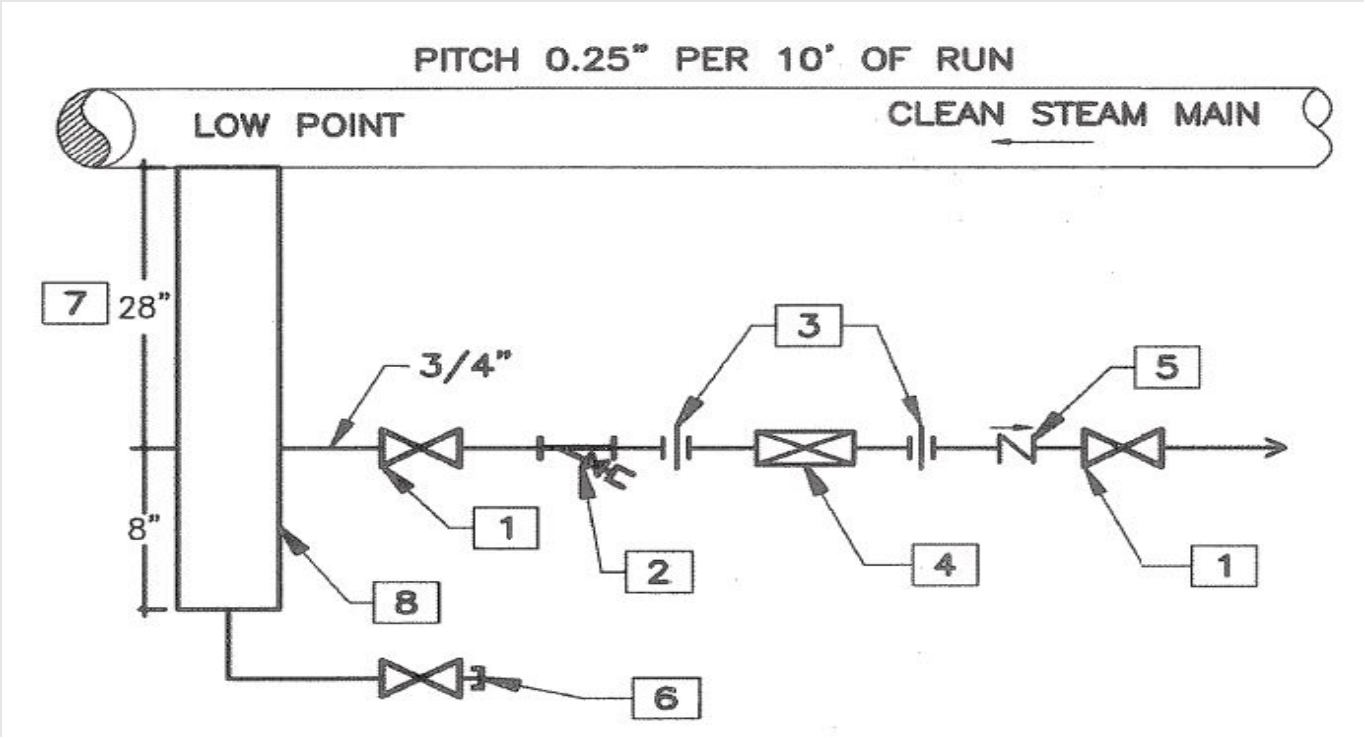


NOTES:

Furnish this type connection when single-line ductwork is indicated as this for branches with more than 25% of the total air flow

Round Duct Branch Connection

Keywords: Air Flow, Sheet Metal, Volume Damper, Main Duct



KEYNOTES:

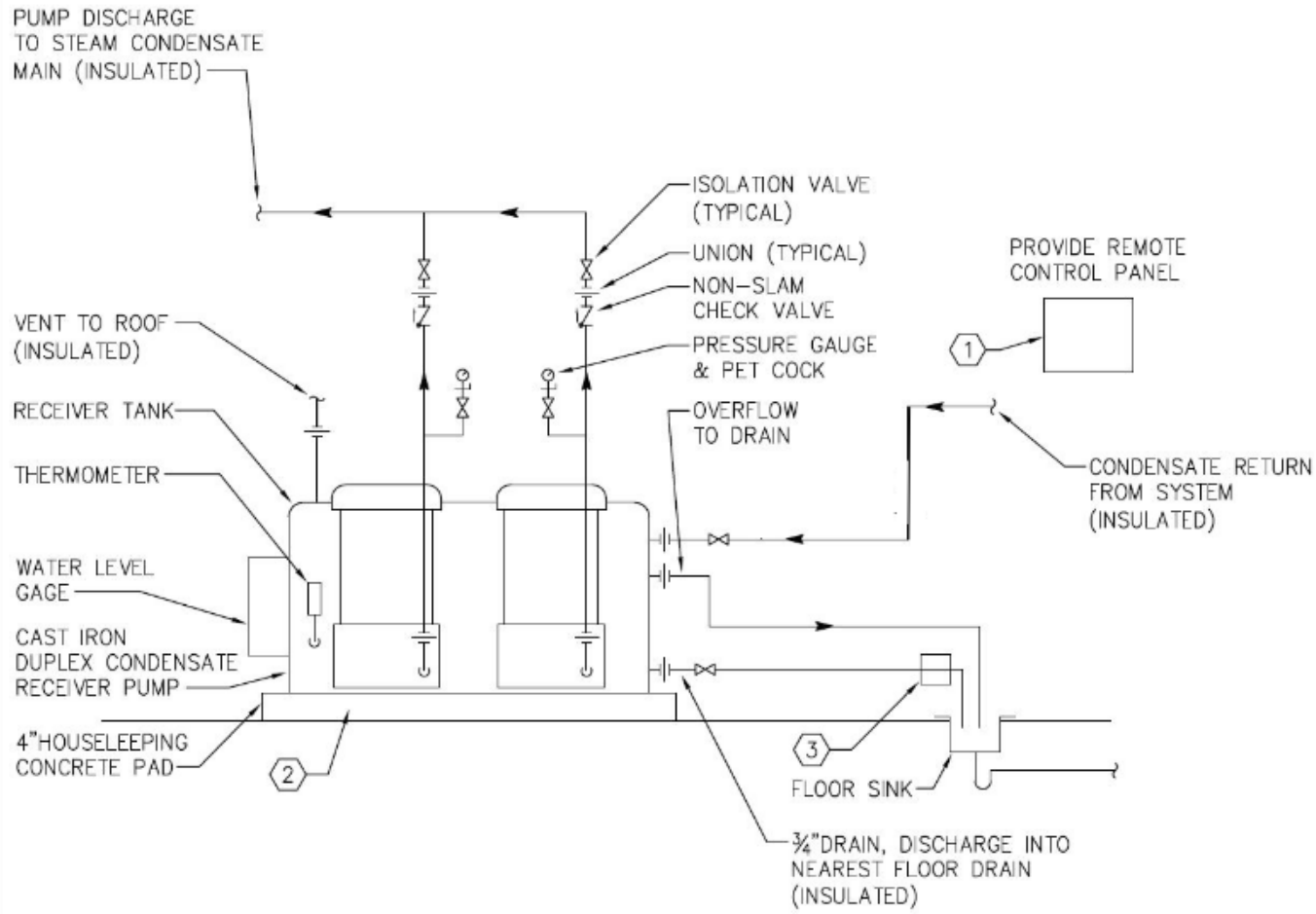
1. Stainless Steel Gate Valve
2. Stainless Steel Strainer w/ Blow Down Ball Valve
3. Stainless Steel Threaded Union
4. Inverted Bucket Trap Stainless Steel Trim
5. Stainless Steel Swing Check Valve
6. ½–inch Stainless Steel Ball Valve for Blow Down Steam Drip Leg Trap Assembly
7. Drip Leg Length 28", Sized for Automatic Warm-Up
8. 1½" Dirt Leg. Provide This Assembly Ahead of Expansion Joints, Bends, Valves, Low Points, PRV and Other Condensate Collection Points Not Shown

NOTES:

All components associated with the clean steam system shall be constructed of Stainless Steel grade 304 or better.

Steam Dirt Leg Trap Assembly

Keywords: Clean Steam Leg, Low Point, Pitch

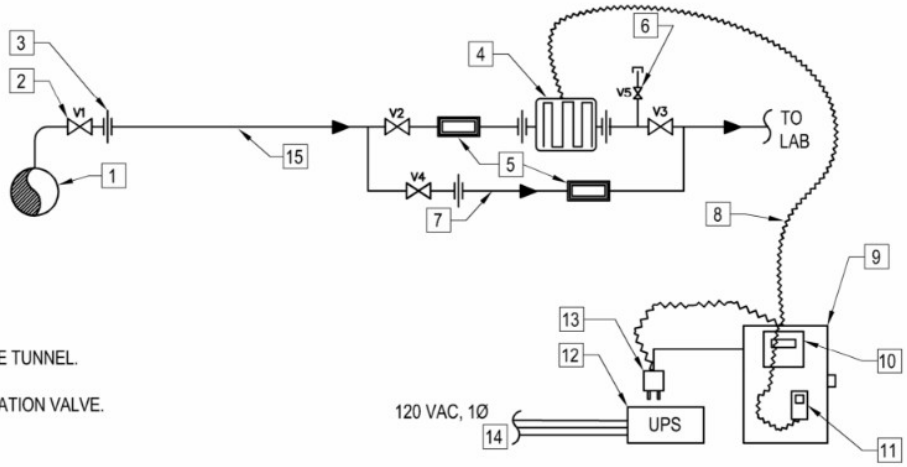


KEYNOTES:

1. Control Panel shall be in a NEMA 3R Enclosure
2. Anchor Unit to Housekeeping Pad per Seismic Zone 4
3. Drain Cooler with 1" ICW Feed, Thermostatically Activate to Lower Temp. to 140 degrees F or Less

Condensate Return Pump Connection

Keywords: Vent, Receiver Tank, Thermometer, Water, Gauge, Duplex, Housekeeping, Overflow, Floor Drain, Control Panel, Union, Pet Cock, Isolation Valve



KEY NOTES:

1. MAIN NITROGEN FEED FROM THE TUNNEL.
2. MAIN GASEOUS NITROGEN ISOLATION VALVE.
3. UNION (TYPICAL).
4. ALICAT "M" SERIES NITROGEN MASS FLOW METER WITH RTU-485 MODBUS COMM. PROTOCOL UNLESS NOTED OTHERWISE. UNITS OF DISPLAY AND MEASUREMENT SHALL BE IN CUBIC FEET.
5. INLINE PARTICULATE FILTER.
6. 1/2" OR 1/4" PLUGGED BALL VALVE FOR PURGING AIR.
7. BYPASS PIPE. FULL LINE SIZE WITH DEDICATED ISOLATION VALVE.
8. 8-CONDUCTOR COMMUNICATION AND POWER SUPPLY CABLE (MAXIMUM 12' LONG)
9. ENCLOSURE WITH MOUNTING BRACKET. MCMASTER-CARR CATALOG #6919K2 & #6919K42 PANEL AND PADLOCK TYPE LATCH.
10. ALICAT REMOTE DISPLAY UNIT WITH ALL UNITS READING IN CUBIC FEET.
11. EXTERNAL EATON/DURANT 8-DIGIT TOTALIZER, BATTERY OPERATED, JUMPERED TO NON-RESETTABLE POSITION. MODEL # E5-024-C0400.
12. UPS, APC MODEL # BE425M.
13. EXTERNAL POWER SUPPLY.
14. LINE VOLTAGE FROM A 15-AMP DEDICATED CIRCUIT PREFERABLY ON EMG POWER.
15. TYPE L, OXY-MED GRADE COPPER PIPE, CLEANED, CAPPED AND NITROGEN FILLED (TYPICAL).

VALVE DESIGNATION:

V1-MASTER SHUT-OFF
V2-METER SHUT-OFF UPSTREAM
V3-MASTER SHUT-OFF DOWNSTREAM
V4-BYPASS VALVE
V5-PURGE VALVE

GENERAL NOTES:

1. FOR PIPE AND METER SIZE, REFER TO PLANS AND SPECIFICATIONS.
2. REFER TO DESIGN GUIDELINE FOR MATERIAL SPECIFICATION, MAKES AND MODEL NUMBERS.
3. PREFERRED DISPLAY PANEL INSTALLATION IS 6'-0" ABOVE FINISHED FLOOR (AFF); 8'-0" AFF MAXIMUM.

NITROGEN MASS FLOW METER PIPING DIAGRAM

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Nitrogen Meter Piping Diagram

Nitrogen Mass Flow Meter Installation Requirements

a. Demand flow rate and exact installation location shall be analyzed by Caltech project team and/or mechanical engineer in order to select a mass flow meter with proper flow rate range and an optimal installation location.

b. Each installation will require a full line size bypass pipe to accommodate calibration, repair and replacement of the mass flow meter while maintaining undisrupted delivery of nitrogen to the building and/or individual laboratories.

c. A 5.0-9.0 micron particulate filter shall be installed upstream of the Nitrogen mass flow meter (similar to ILF-xxx-40).

d. Isolation ball valves are required upstream and downstream of the mass flow meter in addition to the bypass pipe.

e. Mass flow meter installation shall include an APC UPS battery backup system with 350VA capacity. Model APC BE425M.

f. Provide a heavy duty IDEC PS5R-VA24 dedicated power supply, 25’ long DC-251 communications cable and 12’ long RS-232 cable.

g. Each mass flow meter installation shall include an external replaceable battery powered Eaton model E5-24-C0400 totalizer with 8-digit display panel read-out capability. External totalizer shall be jumped to disable the reset button.

h. Display panels shall be housed inside an enclosure with a clear Plexiglas front panel and lockable door.

i. Display panel enclosure shall be installed in a clear and visible location. Exact location shall be reviewed and approved by Caltech project manager and/or mechanical engineer.

j. Unless noted otherwise, Nitrogen mass flow meter shall be “ALICAT” M series mass flow meter with an external monochromatic display panel and pulse output. Certain applications will require an integral display panel. Refer to specifications for the specific configuration of the mass flow meter.

k. Annual calibration of Nitrogen mass flow meters is required. Facilities Management will be responsible for the central building mass flow meter and each PI will be responsible for maintenance and calibration of their lab mass flow meter.

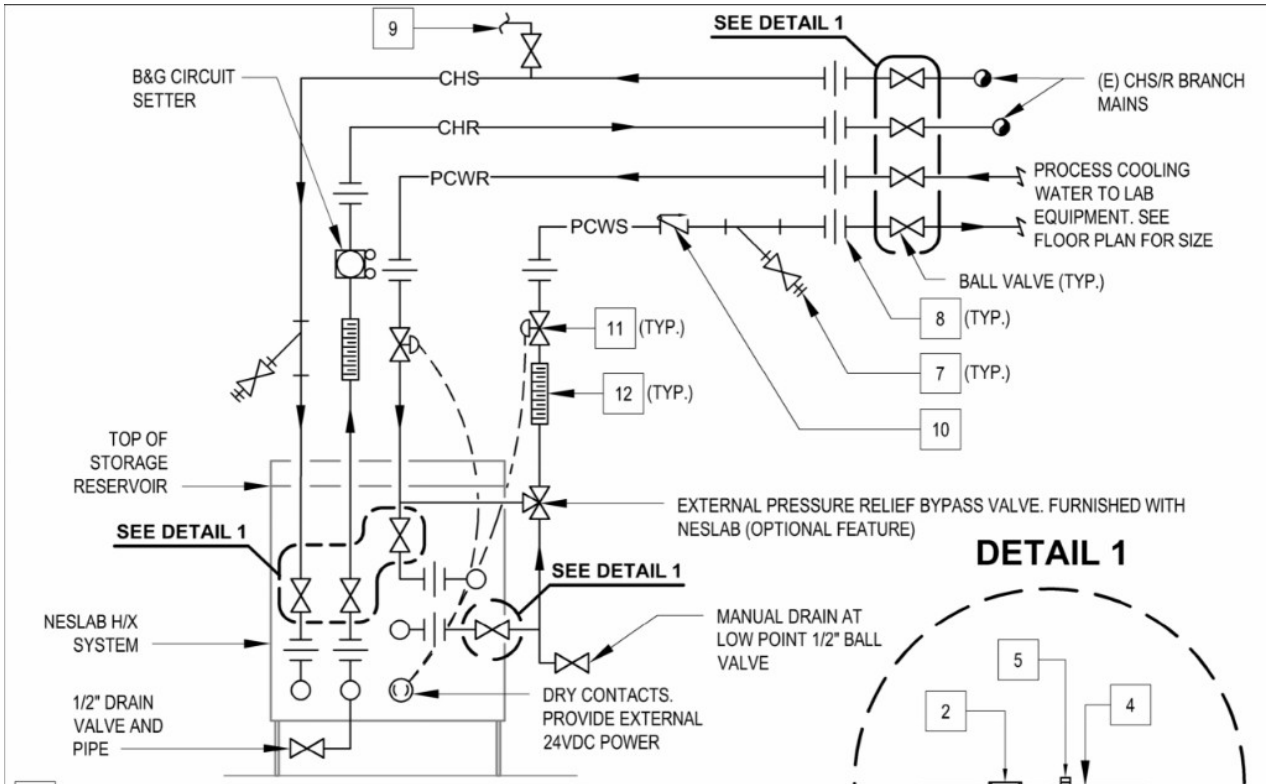
l. Installation shall be done in such manner as to maintain cleanliness of the pipe and all associated components. All components shall be bagged and sealed from the factory to protect against contamination. All pipe work shall be Sealed OXY_MED grade copper pipe and purged with Nitrogen gas during the brazing process. Nitrogen pipe shall be sized based on the expected demand flow rate.

m. Provide a ½–inch purge valve to allow purging of any trapped air in the system prior to delivery.

n. When readily available, mass flow meter shall be fed from circuit on emergency power. Otherwise, a dedicated 15A circuit is acceptable.

o. Mass flow meter installation shall be inspected by Caltech project manager, Caltech mechanical engineer and Caltech PD&C inspector. Prior to installation, contractor is required to consult with Caltech mechanical engineer to determine the exact mass flow meter location and installation details.

p. Proper operation of the mass flow meter shall be observed and verified by Caltech project manager and mechanical engineer.



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3 BRASS OR COPPER NIPPLE (MxM)

4 MALE ADAPTER SOFT-SOLDERED OR PROPRESSED TO PIPE.

5 THREADED UNION (FxF). ISOLATION VALVE INSTALLED ON THE BRANCH SIDE DOWNSTREAM OF THE ISOLATION VALVE.

6 VALVE HANDLE TO BE INSTALLED TO POINT IN THE DIRECTION OF FLOW WHEN IN FULLY OPEN POSITION AND CONVENIENTLY ACCESSIBLE. INSTALL STEM EXTENSIONS ON ALL INSULATED PIPES.

7 Y-STRAINER WITH BALL VALVE & HOSE END CONNECTION:
1. **2" & DOWN:** WATTS LF777 ------ **2" & UP:** WATTS 77F

8 FIP X FIP BRONZE UNION W/ THREADED ENDS

9 MANUAL AIR VENT AT HIGH POINTS. PIPE TO NEAREST APPROVED RECEPTOR WITH 1/4" SOFT COPPER TUBING (TYP. FOR CHS/R)

10 SPRING LOADED BRASS CHECK VALVE (1.0 PSIG CRACKING PRESSURE)

11 ELECTRIC ACTUATED SOLENOID VALVE NORMALLY CLOSED INTERLOCKED TO NESLAB PUMP VIA DRY CONTACTS ASCO 8210G008DC24/DCD (TYP.2)

12 "RYAN-HERCO" FLOW METER WITH BRASS END FITTINGS (TYP.)

NOTES:

1. NESLAB UNIT WILL BE EITHER OFCI OR CFCI. SEE SCOPE NARRATIVE FOR SPECIFICS.
2. FOR PIPE SIZES REFER TO FLOOR PLANS OR SCOPE NARRATIVE.
3. INSULATE CHILLED WATER AND PROCESS COOLING WATER PIPES AS PER SPECIFICATIONS.
4. TYPE "L" COPPER PIPE FOR ALL PIPE WORK.
5. ANCHOR NESLAB UNIT TO CONCRETE SLAB AND OR WALL VIA "L" BRACKETS AND EXPANSION ANCHOR BOLTS TO RESIST MOVEMENT AS SUITABLE FOR SEISMIC ZONE 4.
6. FOR APPLICATIONS WHERE DISTRIBUTION PIPING IS BELOW NESLAB RESERVIOR, PCWS&R WILL ACTUALLY BE INSTALLED BELOW THE HIGH-WATER LINE INDICATED IN DETAIL.

PROCESS COOLING WATER HEAT EXCHANGER

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APPENDIX XXI – BSL Laboratory Design Guide and Features

BSL level	Ante room	Door / access	Walls	Flooring	Windows	Ceiling	Lab bench and work surfaces	Hand sink (DCW+DHW)	(IC
BSL1 / general biology lab	NR, OPT	REQ	NSR	VCT	Screen required if open to outdoors	No specific requirements	Impervious to water and resistant to heat and chemicals	Sink to promote hand washing when leaving the lab. Faucet needs vacuum breaker.	
BSL2 / Tissue culture room	NR, OPT	Self-closing door and possible electronic access control	NSR	Vinyl sheet, or rubber tile or rubber sheet	Windows are not recommended. Seal windows if existing	Cleanable ceiling tile	Impervious to water and resistant to heat and chemicals	Motion-activated sensor type mixing faucet located near the exit door. Faucet needs vacuum breaker.	a pro re
BSL2 / HIV research	Required	2 sets of doors (Anteroom) Self-closing Access control (Card)	Epoxy Paint. Smooth finish, easily wiped down. Sealable penetrations	Vinyl sheet, monolithic or seamless flooring	Seal inside windows, if existing	Hard lid, epoxy painted with all penetrations sealed or clipped accessible cleanable ceiling system	Impervious to water and resistant to heat and chemicals	Sink - hands free (motion activated) Near the exit door and in the anteroom. Faucet needs vacuum breaker.	a pro re
BSL3	Required	2 sets of doors (Anteroom) Self-closing and interlocked Access control (Card) – Possible biometric control Self-closing Access control (Card)	Smooth finish, easily wiped down /Epoxy All penetrations sealed	Monolithic / Seamless Epoxy	Seal inside windows, if existing	Hard lid, epoxy painted with all penetrations sealed	Impervious to water and resistant to heat and chemicals	Sink - hands free (motion activated) Near the exit door and in the anteroom. Faucet needs vacuum breaker.	a pro re

NSF= No Specific Requirement | NR = Not Required | NSR = No specific requirement | DP = Differential pressure

REQ= Required | OPT = Optional | RCMND= Recommended | Temp= Temperature

The table is provided as general guidance and the design team shall confirm the specific requirements on a project basis with the Caltech project manager.

	HVAC features				
BSL level	**Air flow Direction**	**Room pressurization**	**Room air exhaust**	**Single-pass air**	**ACPH**
BSL1 / general biology lab	From adjacent room(S) to the BSL lab or as per EH&S directive or lab programming requirements	Negative to adjacent room(s) unless otherwise directed by the EH&S officer	No return air to the main building air handling system is allowed	Required. Recirculation allowed only within the lab when using a Fan coil unit	Min. 6.0 during occupi and 4.0 during unoccupied
BSL2 / Tissue culture room	From adjacent room(S) to the BSL lab or as per EH&S directive or lab programming requirements	Negative to adjacent room(s) unless otherwise directed by the EH&S officer	No return air to the main building air handling system is allowed	Required. Recirculation allowed only within the lab when using a Fan coil unit	Min. 6.0 during occupi and 4.0 during unoccupied
BSL2 / HIV research	Anteroom negative to adjacent space and work room negative to anteroom	Negative to adjacent room(s) in a cascaded fashion unless otherwise directed by the EH&S officer	Dedicated Exhaust unless effluent goes through HEPA filters before being discharged – no recirculation to any other part of the building (either direct roof exhaust, or HEPA-filtered air into the central exhaust plenum)	Required. Recirculation allowed only within the HIV lab when using a Fan coil unit	Min. 6.0 during occupi and 4.0 during unoccupied or as direc by the EH&S officer or programing requireme
BSL3	Anteroom negative to adjacent space – work room negative to anteroom unless directed otherwise by the EH&S officer	Negative to adjacent room(s) in a cascaded fashion unless otherwise directed by the EH&S officer	Dedicated Exhaust – Parallel HEPA bank (bag-in/bag out, with bubble-tight isolation dampers and decontaminate ports) – Dedicated parallel redundant fans, Exhaust ducts are welded stainless steel, pressure tested post-installation.	Required	Min. 8.0-10.0 during occupied and 4.0 durir unoccupied or as direc by the EH&S officer or programing requireme

NSF= No Specific Requirement | NR = Not Required | NSR = No specific requirement | DP = Differential pressure

REQ= Required | OPT = Optional | RCMND= Recommended | Temp= Temperature

The table is provided as general guidance and the design team shall confirm the specific requirements on a project basis with the Caltech project manager.

	HVAC Controls features				
BSL level	**DDC / Pneumatic**	**Controls – HVAC / Mechanical**	**Local room temperature adjustment / Thermostat**	**Local Temperature monitoring**	**Lo differe mo**
BSL1 / general biology lab	Pneumatic controls is acceptable. DDC is recommended	Default building controls	NR	NR	
BSL2 / Tissue culture room	Pneumatic controls is acceptable. DDC is recommended	Default building HVAC, Possible air flow reversal monitoring (pressure sensors) and adjusting when required by EH&S or the PI	NR	NR	
BSL2 / HIV research	DDC is Required	Dedicated controls for prevention of airflow reversal – Supply and Exhaust fans or TAUs auto adjust to keep the room negative. Room shall not be allowed to be positive. Pressure sensor Failure mode triggers room to neutral pressure	Required	NR	R
BSL3	DDC is Required	Dedicated controls for prevention of airflow reversal – Lab Suite shall never be positive. Exhaust fans to alternate as needed to maintain room negative pressure. Supply-Exhaust fans/TAUs auto adjust. Automatic damper close/seal, if loss of negative pressure	Temperature sensor located inside the room and thermostat located outside to accommodate sanitization of the room and its contents	NR	R

NSF= No Specific Requirement | NR = Not Required | NSR = No specific requirement | DP = Differential pressure

REQ= Required | OPT = Optional | RCMND= Recommended | Temp= Temperature

The table is provided as general guidance and the design team shall confirm the specific requirements on a project basis with the Caltech project manager.

Power and Lighting

BSL level	Normal Power Redundancy	Standby Power	Circuiting	
BSL1 / general biology lab	NR	NR	2 Receptacles per Circuit	Illum re
BSL2 / Tissue culture room	Preferred	BSCs, Safety Centrifuges, Incubators Laboratory Exhaust	Dedicated Circuits for Equipment	Illum reflect (v
BSL2 / HIV research	Preferred	BSCs, Fume Hoods, Freezers, Laboratory Exhaust, Autoclaves	4 Receptacles per Circuit, Dedicated Circuits for Equipment	Illum re
BSL3	Preferred	BSCs, Safet Centrifuges, Sealed Rotors, Laboratory Exhaust, Autoclaves	Dedicated Circuits for Equipment	Illum reflect

NSF= No Specific Requirement NR = Not Required NSR = No specific requirement DP = Differential pressure

REQ= Required OPT = Optional RCMND= Recommended Temp= Temperature

The table is provided as general guidance and the design team shall confirm the specific requirements on a project basis with the Caltech project manager.

APPENDIX XXII – OLAR REQUIREMENTS

The engineering and architectural criteria provided in the National Research Council (NRC) Guide for the Care and Use of Laboratory Animals: Eighth Edition will be followed. The criteria established in the Guide are required to maintain Caltech's NIH Animal Welfare Assurance, to maintain AAALAC accreditation and to ensure efficient, quality animal care.

Engineering Criteria:

HVAC system:

1. HVAC systems must be designed for reliability (including redundancy where required), ease of maintenance, and energy conservation; able to meet requirements for animals as specified in the Guide; and flexible and adaptable to the changing types and numbers of animals and equipment maintained during the life of the facility. They should be capable of adjustments in and ideally able to maintain dry-bulb temperatures of ±1°C (±2°F).

2. Air Handling Units and Exhaust Fans dedicated to serving animal holding rooms shall be designed for 100% redundancy. In the event of an HVAC system or component failure, secondary or redundant systems should supply facility needs at a full capacity, address the adverse effects of loss of temperature control, and, where necessary, maintain critical pressurization gradients. It is essential that life-threatening heat accumulation or loss be prevented during mechanical failure.

3. All air handling unit fans shall be direct driven (i.e. no belts)

4. Main ducts shall be equipped with pressure sensors to allow the fan to compensate for filter loading and other conditions that may affect airflow rates.

5. Emphasis must be placed on avoiding system features that may result in generation of high frequency noise and/or vibration. In noise sensitive area (e.g., behavior testing rooms), consult with an acoustical engineer and provide inline duct sound attenuators as needed. Consideration shall be given to the hearing range of the species that will be used in the specified areas.

6. The system shall be configured to optimize airflow within the floor plan for the facility and provide for desired air change per hour and air pressure differentials (see below for detail).

7. Air supply and exhaust ducts should be positioned as necessary to optimize air circulation within each room with full coverage and minimal draft. Supply air should not be located directly over housing racks to decrease drafts. When specifically requested by project manager, a CFD analysis shall be performed on rooms with critical requirements.

8. Air supply and exhaust grilles shall be flush mounted to the ceiling and constructed of aluminum or stainless materials to facilitate ease of sanitation. Perforated face plates in lieu of slotted grilles are required.

9. A thimble connection may be used to remove HEPA filtered exhaust air from ventilated rodent housing racks if the thimble also allows for removal of room air.

10. Thermostats in animal holding room should be located away from doors to prevent drafts from impacting room temperatures.

11. A redundant or secondary temperature and relative humidity monitoring probe shall be placed in an air exhaust duct in each animal holding room and connected to central plant's BMS for continuous 24/7/365 monitoring to allow for rapid response in the event that temperatures or relative humidity vary outside of a pre-defined range. Secondary temperature probe/controller must be independent from the primary temperature sensor/controller system and initiate a fail-safe mode in the event that a temperature probe/controller fails. (i.e. force the reheat control valve to fully closed position and cooling control valve to fully open position)

12. Provide single pass 100% fresh air supply. Care must be taken to ensure that air supply intake will be located such that it does not contain air that might be contaminated with lab odors, car fumes, cigarette smoke, etc. as this may disrupt behavior of the animals.

13. Central station Air Handling Units serving animal rooms shall be equipped with UVC light emitters to minimized growth of biological organisms and associated air contamination due to bio-matter growth.

14. Exhaust air from animal related facilities shall not get entrained into return air or ventilation air of offices, public hallways or general lab areas as negative pressure events could result in spread of allergens and odors to these areas resulting in human health concerns.

15. The heat load generated by the animal housing racks, freezers, hoods, computers, etc. shall be taken into account when planning the HVAC system.

16. Steam production and containment must be taken into account when planning the exhaust via canopies in the cagewash areas.

17. All areas shall be air balanced during the commissioning process.

18. All mechanical aspects shall be fully commissioned by an independent commissioning agent at the completion of the project and also 11 months after completion to ensure that design intent was satisfied. Air balance reports for each room shall include the number of air changes, supply air and exhaust air flow rates, relative pressurization relationship values, room name/number and corresponding mechanical systems serving each room.

19. Humidifiers shall use de-ionized water only and shall be constructed of stainless steel to resist corrosion.

20. Space humidification shall be controlled and supplemented on a system or zone basis as required and /or requested by OLAR. Control of humidification in individual holding spaces may be desirable for selected species with reduced tolerance for low or high relative humidity. The specific requirements for each space shall be defined during the programming phase of the project.

21. Mechanical areas to be provided with air circulation to prevent accumulation of heat and steam that will result in damage to electronic equipment.

22. Temperature Control Valves serving reheat coils shall fail in the closed position and the HVAC system must be equipped with a high-temperature cut-off mechanism to prevent space overheating and animal loss with valve failure.

23. Installation of steam pre-heat coils or re-heat coils is strictly prohibited.

HVAC Pressurization and number of ACPH

24. A properly designed and functioning HVAC system is essential to provide environmental and space pressurization control. Pressurization assists in controlling airborne contamination and odors by providing directional airflow between spaces. Areas for soiled cagewash quarantine, holding, and use of animals exposed to hazardous materials, and housing of non-human primates should be kept under relative negative pressure, whereas areas for surgery or clean equipment storage should be kept under relative positive pressure with clean air.

25. Pressurization shall be achieved using pressure independent terminal air units for supply air and exhaust air in each room and by maintaining a volumetric offset between SA and EA flow rates.

26. Differential pressure (DP) visual indicator (magnahelic gauge) shall be provided to show the relative pressurization relationship in animal holding rooms, surgery and animal preparation spaces, and other spaces as required by OLAR.

27. Where required, an electronic DP transmitter shall be provided with connection to BMS for local and/or remote alarming purposes.

28. As applicable, animal holding rooms shall be positive to the adjacent procedure room. Procedure rooms directly adjacent to animal holding rooms and leading to central corridors should serve as an airlock between the animal holding room and the central corridor. However, the ability to change the air pressure differentials of all rooms should be flexible so that air pressure differentials can be changed to accommodate rapidly changing needs for the research program.

29. The anteroom/gowning area shall serve as an air lock and shall be negative to the adjacent procedure room and negative to the central facility hallway. The air lock leading from internal animal facility areas to the public corridor shall be maintained under negative pressure and shall be used to limit exposure of public areas to allergens and odors.

30. Prep rooms shall be maintained under negative pressure in most cases.

31. Procedure rooms used for survival surgery procedures involving USDA covered species (non-human primates) shall be maintained under positive air pressure.

32. The behavior testing rooms shall be maintained under positive pressure.

33. A minimum of 10-15 air changes per hour (ACPH) shall be provided in animal holding rooms including the long term behavior holding rooms in which animals shall be housed for greater than 24 hours. Consult with OLAR regarding specific # of ACPH for each room.

Temperature, relative humidity and filtration/extraction:

34. Unless otherwise noted, the HVAC in the animal holding room shall be designed to provide room temperature at the desired ranges +/– 2º F (71–75º F) for rodent species and temperature for other animal species as specified by OLAR. A local thermostat with local temperature control shall be provided for each animal holding and behavior test room with a redundant temperature sensor in the exhaust air duct.

35. Relative humidity shall normally be maintained within 45-55% range. Relative humidity range of 30-70% is acceptable if deviations outside the desired range are infrequent, minimal, and of short duration.

36. Humidity sensors shall be mounted inside exhaust air ducts and have a 2% accuracy.

37. Downdraft tables or local extraction (fume) hood shall be installed in a subset of prep rooms to remove fumes associated with perfusion procedures.

38. AHUs shall be equipped with MERV8 pre-filters and MERV13 or 14 final filters per OPR.

39. Surgery suites for USDA covered species shall be equipped with 95% final filtration at termination.

Electrical:

40. Electrical outlets will be flush mounted and provided with moisture proof covers. Covers will accommodate plugs for housing equipment and animal transfer stations/BSCs. Electrical outlets should be oriented such that the moisture proof cover will reduce water exposure from above the outlet.
41. Electrical outlets near the vicinity of sinks will be GFI protected.
42. Emergency power will be provided to all electrical outlets in the animal holding rooms.
43. Duplex electrical outlet for the ventilated racks must be located at a height dependent on rack height (e.g. above 48”) for ease of connection to caging system and to avoid damaging outlets when moving racks.

Lighting:

44. Light fixtures will be recessed mounted, moisture proof 1'x4' fluorescent fixtures that are sealed for clean environments, with one piece stainless steel overlap door, inverted .125 acrylic prismatic lens to withstand 100 psi hose down.

45. LED 4000K with lighting control will be installed that will provide the necessary foot-candles of light for the specific application (e.g. species) in the space.

46. Recess mounted, digital, battery backup 120 V light timers will be used to provide light cycles in the animal holding and behavior testing rooms. Digital (Intermatic ET170 series electronic 7–day timer or Tork ET 103C) light timers are preferred. Some rodent holding areas may require a light timer that provides dawn/dusk light transition. OLAR will provide confirmation of lighting requirements for the species to be housed.

47. A manual override light timer switch, which will allow for dual light levels, will be installed in animal holding rooms. This switch will be used to increase light levels from 30 foot-candles to 50 foot-candles. The switch should allow for defined periods of light not greater than 2 hours after which the light will automatically be turned off (e.g., 15 minutes, 30 minutes, 1 hour, 2 hours).

48. An additional switch will be provided to allow for control of a single light bulb within each ballast and provide red light for specific applications (e.g. rodent holding).

49. Light timer controls will be located outside of animal holding rooms and must be flush mounted. A cloud-based lighting control system with local override is preferred.

50. Light levels will be 30-50 ft-candles 1 meter above the floor in rodent holding rooms.

51. Optimal wavelength for the light bulbs for the rodent holding rooms is ~550 nm.

52. Light levels in procedure rooms and cage wash areas should provide typical work appropriate light levels.

53. Gowning and anterooms may be provided with motion detector light switches.

54. Procedure rooms may be provided with standard on/off light switches.

55. Light switches should be moisture proof.

Plumbing/Water:

56. The procedure room(s) will be equipped with a stainless steel sink that provides hot and cold potable water.

57. Emergency eye wash/shower station(s) will be installed per the EH&S Office recommendation. The eye wash/shower station(s) shall be located such that it does not obstruct desired work flow patterns.

58. All openings around piping, electrical boxes, door jambs, etc. will be sealed to prevent entry of vermin and insect pests.

59. Floor drains will be at least 3" diameter. If removable drain covers are provided, OLAR staff will provide desired specifications. The drain cover must be flush with the floor to allow for ease of cart traffic.

60. Pit drain large enough to accommodate a ventilated rack or rack washing cart will be located in front of rack washer and autoclave on clean side.

61. Mechanical spaces with water production and cagewash spaces shall be provided with a water flood alarm that is connected to the BAS, to provide alerting to a flood issue that could damage sensitive equipment such as motors and pumps. Housekeeping pads should be provided to elevate sensitive equipment in areas where flooding may occur.

62. Floor sinks will be provided in clean and dirty cage wash and will be equipped with metal covers that can be removed to facilitate ease of cleaning. Metal covers must be flush with the floor level, such that rolling equipment will not be caught in grate.

63. Depending on location of cagewash, trough drains may be installed to prevent hallway flooding in event of flood in cage wash area.

64. In each procedure space, a clean water source and location for dirty water disposal required for mop buckets. Facilities should be equipped with a janitor closet with a floor sink.

65. A water softener is required for autoclave and rack washer.

66. Autoclave should be plumbed with non-amine water.

67. Chemical connections and storage (for rack washer) should be in a separate storage space, to allow delivery from the loading dock without entering the animal facility.

Services:

68. BSCs will be equipped with CO2 and building vacuum. Recessed outlets are desirable.
69. O2 flush mounted medical grade gas outlet (Amico Alert-1 series) will be provided at BSC hoods in procedure rooms and surgery spaces.
70. Oxygen and carbon dioxide gas cylinders will be stored in a centralized gas cylinder storage designed for this purpose with a central manifold.
71. Data will be provided in each animal housing and procedure space and in the cagewash area.
72. High pressure air is required in gnotobiotic housing areas.

Safety:

73. Fire extinguisher set in a recessed wall cabinet to prevent damage from cart traffic.
74. Fire sprinklers should be located such that they minimize damage to equipment and live animals if triggered. Fire sprinklers should be clean room design quality and flush mounted to ceiling.
75. Fire alarm must be below the hearing range of rodents (frequency < 500 Hz). Audible fire alarms should be outside of animal housing rooms. Strobe lights should be located in the animal housing rooms.
76. Eye wash/shower – Guardian (GBF2452) Recessed Safety Station with exposed shower head, rain pan and daylight drain, clean room construction.
77. Door swing should expedite safe work flow patterns.

Architectural Criteria

Floors:

78. The floor will consist of material that will withstand constant contact with caustic sterilant (i.e. Clidox and accelerated hydrogen peroxide) and can withstand point pressure on casters for racks that may exceed 500lbs. Radial cove (6 inches) to join with wall should be seamless to drywall to prevent accumulation of debris at wall transition. Radial coves shall have backing to support surface materials.
79. Floor material type and color to be approved by OLAR personnel. Epoxy or urethane based system are preferred.
80. Detail at floor drains/sinks to be approved by OLAR personnel

Walls:

81. New walls will be constructed of ½" gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials. Cove radius dimension to be approved by OLAR personnel.
82. Wall materials will facilitate sanitation while reducing vibration and noise from adjacent areas.
83. All wall surfaces will be painted with two coats of epoxy paint over one coat of primer.
84. Sani-rail and stainless steel corner guards will be installed in high traffic areas (e.g. hallways, food and bedding room, storage room) and in areas with large equipment (e.g. cagewash, non-human primate housing spaces) to protect wall

finishes. Plastic wall guard material will be placed in animal holding rooms at the level of contact with biosafety cabinets and animal housing racks.

85. Backing will be placed in areas intended for installation of Sani-rail cleaning tool holders.

Ceiling:

86. Air supply grilles will be recessed so they are flush with the surface of the ceiling.
87. The sprinkler heads will be concealed type, sealed flush-mounted cover type to facilitate cleaning.
88. The ceiling will be constructed of gypsum board and painted with one coat of primer and two coats of epoxy paint.
89. Ceiling access panels will be minimum 24" x 24, stainless steel, and gasketed to prevent entry of vermin (clean room seal). They will be located outside of the animal housing rooms. Ceiling entry from an interstitial space above the facility is preferred in lieu of ceiling access in the animal facility corridors.
90. Animal facilities should have hard lid ceilings. Exposed duct work is to be avoided.

Doors:

91. Doors and door frames will be constructed of FRP, stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set hinges, an integral bottom sweep, hold-open closure mechanism, and a view window.
92. The door closure mechanism should be mounted on the inactive side (back) of the door.
93. Doors into animal housing rooms will meet soundproof specifications.
94. Internal doors will have a window.
95. Entry doors from the central public corridor into the facility will open inward and will not be equipped with windows for security reasons.
96. Entry doors from a public corridor will be equipped with an electronic card reader for security purposes.
97. Animal room doors will be equipped with red colored vision glass in view windows (with internal blinds) and a hold open feature to allow for ease of movement of large equipment (e.g., racks and carts) in and out of the room.
98. All animal housing and procedure room doors will be a minimum of 42"x 84" to allow for ease of access when moving isolators, ventilated racks/ supply carts. Storage area doors should be wide enough to accommodate a pallet entrance.
99. Door jambs will be supplied with Borax or similar material to prevent insect nesting.
100. To facilitate ease of floor sanitation, doorstops must be placed on the wall behind the door rather than being floor mounted.
101. Doors to the cagewash facility and NHP areas (and other specific areas as indicated by use) must be equipped with push plate openers.

Sinks and cabinetry:

102. Cabinetry, sinks (including fixtures) and counter tops will be constructed of stainless steel.
103. Cabinetry will extend to the ceiling to prevent gaps where dust can accumulate.

Security:

104. A proximity security proximity reader will be installed on the external access door (door between the public hallway and the anteroom).
105. Where the design plan calls for a security proximity reader and an auto door opener mechanism, OLAR personnel to approve whether the security reader should operate the door opener mechanism.
106. A security camera connected to Campus Security will be maintained at external access door(s).

Fixed and Movable Equipment:

Animal Housing Racks and Associated Equipment (varies by species but could include lifts, ventilated or static racks)

Biosafety cabinets (Class 2A1)

Computers for task stations

Metro cabinets (plastic enclosed)

Storage racks with covers

Carcass disposal refrigerator/freezer(s)

Glass dry erase boards

Clock (s)

Telephone(s)

Hose reel – wall recessed mounted in NHP areas and ceiling mounted in cagewash areas

Paper towel dispensers

Sani-rail tool holder

Glove box holders

Desks

Chairs (non-fabric)

Room type	Walls	Paint	Wall protection	Ceiling	Floor	Doors and Door Frames	Door Windows
Rodent quarantine	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	Plastic wall guards. Stainless steel corner guards on high traffic areas/columns.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Red colored vi
Rodent holding	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	Plastic wall guards. Stainless steel corner guards on high traffic areas/columns.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Red colored vi
Anterooms/Gowning	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	4 in sanirail. Stainless steel corner guards.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Central public c will open inwar with windows f
Procedure	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	Plastic wall guards. Stainless steel corner guards on high traffic areas/columns.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Red colored vi
Feed and Bedding Storage	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	4 in sanirail. Stainless steel corner guards.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Double-door (2 x 42" x 84").	Clear
Operating/Surgical Suite	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	Plastic wall guards. Stainless steel corner guards on high traffic areas/columns.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Double-door (2 x 42" x 84").	Stainless steel metal and equi hardware (han bumper rails), an integral bott closure mecha x 84").
Cage wash, Dirty	FRP	n/a	4 in sanirail. Stainless steel corner guards.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- slight grit with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism, and a view window. Double door (2 x 42" x 84").	Clear
Cage wash, clean	FRP	n/a	4 in sanirail. Stainless steel corner guards.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- slight grit with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism, and a view window. Double door (2 x 42" x 84").	Clear

Room type	Walls	Paint	Wall protection	Ceiling	Floor	Doors and Door Frames	Door Windows
Zebrafish quarantine	FRP	n/a		Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- slight grit with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Flap cover
Zebrafish holding	FRP	n/a		Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- slight grit with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Flap cover
Frog holding	FRP	n/a		Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- slight grit with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Flap cover
Rodent Behavioral	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	Plastic wall guards. Stainless steel corner guards on high traffic areas/columns.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Red colored vi
Avian holding	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	Plastic wall guards. Stainless steel corner guards on high traffic areas/columns.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Flap cover
Avian quarantine	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	Plastic wall guards. Stainless steel corner guards on high traffic areas/columns.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Flap cover
Tree Shrew Holding	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	Plastic wall guards. Stainless steel corner guards on high traffic areas/columns.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Flap cover
NHP holding	FRP with 4in sanirail	n/a	4 in sanirail. Stainless steel corner guards.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Flap cover
NHP quarantine	FRP with 4in sanirail	Two coats of epoxy paint over one coat of primer.	4 in sanirail. Stainless steel corner guards.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Flap cover

Room type	Walls	Paint	Wall protection	Ceiling	Floor	Doors and Door Frames	Door Windows
General species quarantine	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	Plastic wall guards. Stainless steel corner guards on high traffic areas/columns.	Hard lid. Air supply and exhaust grills must have perforated surface and construction of stainless steel or aluminum for rust prevention.	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Red colored vis
Hallways/Storage areas	½” gypsum board over metal studs with radial coves at the ceiling and wall joints. Radial coves shall have backing to support surface materials.	Two coats of epoxy paint over one coat of primer.	4 in sanirail. Stainless steel corner guards.	Hard lid. Air supply and exhaust grills must have be recessed with perforated surface and construction of stainless steel or aluminum for rust prevention. Ceiling access panels to be 24" by 24" stainless steel, gasketed (clean room seal).	Epoxy- smooth surface with radial cove with backing to support surface.	Stainless steel or epoxy painted hollow metal and equipped with stainless steel hardware (handles, armor plates and bumper rails), off-set piano style hinges, an integral bottom sweep, hold-open closure mechanism. Minimum 42”x 84”.	Central public c will open inwar with windows f

General notes:Animal housing rooms may not be furnished with a door that is directly adjacent to a public hallway. An airlock must be provided to separate animal housing areas from public space.

Motion detectors may not be ultrasound (can be infrared)

The sprinkler heads will be concealed type, sealed flush-mounted cover type to facilitate cleaning.

Door jambs and walls will be supplied with Borax or similar material to prevent insect nesting.
Door stops should be placed on the wall behind the door rather than being floor mounted.

Room type	Room pressure	Minimum # of air changes per hour	HEPA filtration	Air distribution type	Required temperature range (°F)	Required relative humidity range (%)	Single pass SA	Redundant controls	Redundant monitoring with exhaust air sensor control	Redundant supply air capability	Redundant Exhaust air capability	Pressure independent SA	Pressure independent EA	Ind ter ca
Rodent quarantine	Negative to adjacent rooms	10 -15	N/R	CAV	73±2	50±20	Required	Required	Required	100%	100%	Required	Required	Req
Rodent holding	Varies. Positive to /ante room if present. Negative to corridor if immediately adjacent to hall.	10 -15	N/R	CAV	73±2	50±20	Required	Required	Required	100%	100%	Required	Required	Req
Anterooms/Gowning	Negative to corridor and holding room	N/A	N/R	CAV	70±4	50±20	N/R	N/R	N/R	75%	75%	N/R	N/R	N/R
Procedure	Negative to corridor and holding room	10-15	N/R	CAV	70±2	50±20	Required	N/R	N/R	75%	75%	Required	Required	Req
Feed and Bedding Storage	Positive to adjacent rooms	N/A	N/R		61±4	40±20	Required	N/R	N/R	N/R	N/R	N/R	N/R	Req
Operating/Surgical Suite	Positive to adjacent rooms	10-15	Required	CAV	70±2	50±20	Required	N/R	N/R	N/R	N/R	Required	Required	Req
Cage wash, Dirty	Negative to corridor and clean cage wash	N/A	N/R	VAV	70±4	N/A	N/R	N/R	N/R	N/R	N/R	Required	Required	Req
Cage wash, clean	Positive to corridor and dirty cage wash	N/A	N/R	VAV	70±4	N/A	Required	N/R	N/R	N/R	N/R	Required	Required	Req
Zebrafish quarantine	Negative to corridor and to main fish housings	10	N/R	CAV	80.6-82.4	N/A	Required	Required	Required	100%	100%	Required	Required	Req
Zebrafish holding	Varies. Positive to /ante room if present. Negative to corridor if immediately adjacent to hall.	10	N/R	CAV	80.6-82.4	N/A	Required	Required	Required	100%	100%	Required	Required	Req
Frog holding	Negative to corridor	10	N/R	CAV	60.8-68	N/A	Required	Required	Required	100%	100%	Required	Required	Req
Rodent Behavioral	Positive to adjacent rooms	10	N/R	CAV	73±2	50±20	Required	Required	Required	100%	100%	Required	Required	Req
Avian holding	Negative to adjacent rooms	10 -15	N/R	CAV	75-79	50±10	Required	Required	Required	100%	100%	Required	Required	Req
Avian quarantine	Negative to adjacent rooms	10 -15	N/R	CAV	75-79	50±10	Required	Required	Required	100%	100%	Required	Required	Req
NHP holding	Negative to adjacent rooms	10 -15	N/R	CAV	74±2	50±20	Required	Required	Required	100%	100%	Required	Required	Req
NHP quarantine	Negative to adjacent rooms	10 -15	N/R	CAV	74±2	50±20	Required	Required	Required	100%	100%	Required	Required	Req
General species quarantine	Negative to adjacent rooms	10 -15	N/R	CAV	74±2	50±20	Required	Required	Required	100%	100%	Required	Required	Req

Avoid equipment that may produce high frequency noise or vibration
All air handling units shall be direct driven (i.e. no belts). Main ducts shall be equipped with pressure sensors to allow the fan to compensate for filter loading and other conditions that may
Air supply and exhaust ducts should be positioned as necessary to optimize air circulation within each room with full coverage and minimal draft. Supply air should not be located directly ov
shall be performed on rooms with critical requirements.
Air supply and exhaust grills will be flush mounted and perforated (not louvered).
Care must be taken to ensure that air supply does not obtain air that might be contaminated with lab odors, car or chemical fumes, cigarette smoke, pollinating plants, etc. as this may disrupt behavior of the animals. All areas will be air balanced during the commissioning process. ACH will be verified as meeting *Guide* requirements.

References: NRC Guide for Care and Use of Laboratory Animals

NIH Design Requirements Manual, Division of Technology Resources, Office of Research Facilities, 2016.

OLAR Facilities, General Utility Requirements

Room type	General Electrical	Data	Lighting	Plumbing
Rodent quarantine	E- power to outlets. Duplex electrical outlet for the ventilated racks must be located at a height dependent on rack height (e.g. above 48") for ease of connection to caging system and to avoid damaging outlets when moving racks. Outlet covers will accommodate plugs for isolators and hoods. Electrical outlets should be oriented such that the moisture proof cover will reduce water exposure from above the outlet. Data	Yes	LED 4000K with lighting control and red light possible. Light levels will be 30-50 ft-candles 1 meter above the floor with an optimum wavelength of 550nm.	RO water
Rodent holding	E- power to outlets. Duplex electrical outlet for the ventilated racks must be located at a height dependent on rack height (e.g. above 48") for ease of connection to caging system and to avoid damaging outlets when moving racks. Outlet covers will accommodate plugs for isolators and hoods. Electrical outlets should be oriented such that the moisture proof cover will reduce water exposure from above the outlet. Data	Yes	LED 4000K with lighting control and red light possible. Light levels will be 30-50 ft-candles 1 meter above the floor with an optimum wavelength of 550nm.	RO water
Anterooms/Gowning	n/a	No	Typical light levels for work environment and occupancy control. No lighting control.	DCW and DHW, Handwashing sink
Procedure	E- power to outlets Data	Yes	LED 4000K with lighting control and red light possible	DCW and DHW. Portable stainless s with floor sink
Feed and Bedding Storage	n/a	No	Typical light levels for work environment and occupancy control. No lighting control.	
Operating/Surgical Suite	E- power to outlets Data	Yes	Typical light levels for work environment. Surgical light for sterile application.	Needs associated surgical handwas
Cage wash, Dirty		No	Typical light levels for work environment. No lighting control.	DCW and DHW, Clean steam, SCW sink with removable metal grate. Dep location of cagewash, trough drains installed to prevent hallway flooding

Cage wash, clean	Data to equipment	Yes	Typical light levels for work environment. No lighting control.	drains in front of autoclave and rack sink with removable metal grate. Depending on location of cagewash, drains may be installed to prevent ha flooding in event of flood in cage was Needs chemical hoses plumber to ch storage area.
Zebrafish quarantine	E- power to outlets	Yes	LED 4000K with lighting control and red light possible	RO, DCW, DHW, DI to sinks
Zebrafish holding	E- power to outlets	Yes	LED 4000K with lighting control and red light possible	RO, DCW, DHW, DI to sinks, floor si trench drain at door
Frog holding	E- power to outlets	Yes	LED 4000K with lighting control	ICW, DI to sinks, floor sinks and tren door
Rodent Behavioral	E- power to outlets, Data	Yes	LED 4000K with lighting control and red light possible	Varies- may need DCW/DHW for lar rooms
Avian holding	E- power to outlets Data	Yes	LED 4000K with lighting control	R/O water
Avian quarantine	E- power to outlets	Yes	LED 4000K with lighting control	RO water Sink with ICW/ICH
NHP holding	E- power to outlets	Yes	LED 4000K with lighting control	RO Water, ICW and IHW to hose ree drains
NHP quarantine	E- power to outlets	Yes	LED 4000K with lighting control	RO Water, ICW and IHW to hose ree drains
General species quarantine	E- power to outlets. Duplex electrical outlet for the ventilated racks must be located at a height dependent on rack height (e.g. above 48") for ease of connection to caging system and to avoid damaging outlets when moving racks. Outlet covers will accommodate plugs for isolators and hoods. Electrical outlets should be oriented such that the moisture proof cover will reduce water exposure from above the outlet.	Yes	LED 4000K with lighting control and red light possible. Light levels will be 30-50 ft-candles 1 meter above the floor with an optimum wavelength of 550nm.	RO water

General notes: Motion detectors may not be ultrasound (can be infrared)

Fire alarm must be low frequency

Electrical outlets will be flush mounted and provided with moisture proof covers.

Electrical outlets near the vicinity of sinks will be GFI protected.

Light fixtures will be recessed mounted, moisture proof 1'x4' fluorescent fixtures that are sealed for clean environments, with one piece stainless steel overlap door, inverted .125 a

A manual override light timer switch that will allow for dual light levels will be installed in animal housing rooms. This switch will be used to increase light levels form 30 foot-candles the light will automatically be turned off (e.g., 15 minutes, 30 minutes, 1 hour, 2 hours).

An additional switch will be provided to allow for control of a single light bulb within the ballast and provide red light for specific applications (e.g. rodent housing).

Light timer controls will be located outside of animal housing rooms and must be flushed mounted. A cloud-based lighting control system with local override is preferred.

All openings around piping, electrical boxes, door jambs, etc. will be sealed to prevent entry of vermin and insect pests.

Fire sprinklers should be located such that they minimize damage to equipment and live animals if triggered. Fire sprinklers should be clean room design quality and flush mounted

Fire alarm must be below the hearing range of rodents (frequency < 500 Hz). Fire alarms should be outside of animal housing rooms. Strobe lights should be covered with red film
wash/shower – Guardian (GBF2452) Recessed Safety Station with exposed shower head, rain pan and daylight drain, clean room construction.

OLAR Facilities, General Equipment Requirements

Room type	Equipment
Rodent quarantine	Ventilated housing rack(s), animal transfer station (BSC), Sani-rail tool holder, Glove box holder
Rodent holding	Ventilated housing rack(s), animal transfer station (BSC), Sani-rail tool holder, Glove box holder
Anterooms/Gowning	Metro storage cabinet(s) (plastic) and gowning station storage rack (as indicated), white board.
Procedure	Animal transfer station (BSC), Glove box holder
Feed and Bedding Storage	Sani-rail tool holder, Glove box holder
Operating/Surgical Suite	Surgical boom, surgical table with tilt and lift function, surgical lights (specific to species needs),
Cage wash, Dirty	Autoclave (insulated such that the thermal load does not influence animal housing room temperatures. Autoclaves must be supplied with dedicated exhaust canopies). Rack and/or tunnel washer (dependent on species to be housed in facility.
Cage wash, clean	Water softener as required for autoclave and cagewash equipment.
Zebrafish quarantine	Recirculating water delivery housing system with centralized water filtration system.
Zebrafish holding	Recirculating water delivery housing system with centralized water filtration system.
Frog holding	Recirculating water delivery housing system with centralized water filtration system.
Rodent Behavioral	May need hose reel
Avian holding	Dependent on species needs
Avian quarantine	Dependent on species needs
Tree Shrew Holding	Housing racks
NHP holding	Housing racks, Hose reel – wall recessed mounted
NHP quarantine	Housing racks, Hose reel – wall recessed mounted
General species quarantine	Housing racks
Hallways	Computer task stations with ergonomic chairs and telephones. Carcass refrigerator/freezer (location and size dependent on species).

All sinks should have a paper towel dispenser installed.

Metro cabinets will be closed plastic

Storage racks will be supplied with covers

APPENDIX XXIII – FUME HOOD AND RELATED EXHAUST SYSTEMS MEMORANDUM OF UNDERSTANDING (MOU)

LINK to 2026 Laboratory Exhaust Hood V5.5

Ventilation Requirements for Laboratory-Type Hood Operations.

Laboratory-Type Hood: A device enclosed on three sides and top and bottom except for necessary exhaust purposes, designed to draw air inward by means of mechanical ventilation, operated with insertion of only the hands and arms of the user, and used to control exposure to hazardous substances. These devices are also known as laboratory fume hoods.

(c) Ventilation Rates:

(1) Laboratory-type hood face velocities shall be sufficient to maintain an inward flow of air at all openings into the hood under operating conditions. The hood shall provide confinement of the possible hazards and protection of the employees for the work that is performed. The exhaust system shall provide an average face velocity of at least 100 feet per minute with a minimum of 70 fpm at any point, except where more stringent special requirements are prescribed in other sections of the General Industry Safety Orders, such as Section 5209. The minimum velocity requirement excludes those measurements made within 1 inch of the perimeter of the work opening.

General air flow should not be turbulent and should be relatively uniform throughout the laboratory, with no high velocity or static areas; airflow into and within the hood should not be excessively turbulent; hood face velocity should be adequate (at least 100 fpm at a minimum sash opening height of 18")

The design exhaust airflow from a VAV fume hood is the flow required to produce the face velocity that maximizes the containment performance of the hood at its design face opening.

This criterion now links the specification of exhaust airflow to two quantifiable variables that impact containment — face velocity and face opening.

(2) When a laboratory-type hood is in use to contain airborne hazardous substances and no employee is in the immediate area of the hood opening, the ventilation rate may be reduced from the minimum average face velocity of at least 100 feet per minute to a minimum average face velocity of 60 feet per minute if the following conditions are met:

(A) The reduction in face velocity is controlled by an automatic system that does not require manual intervention. The automatic system shall increase the airflow to the flow required by (c)(1) when the hood is accessed.

(B) The laboratory-type hood has been tested at the reduced flow rate according to the tracer gas method specified in Section 7, Tracer Gas Test Procedure, of **ANSI/ASHRAE 110-2016**, Method of Testing Performance of Laboratory Fume Hoods, which is hereby incorporated by reference, and has a hood performance rating of 4.0 AU 0.1 or less. The test may be performed with or without the mannequin described in the **ANSI/ASHRAE 110-2016** tracer gas method.

- *AM indicates the test setup is "As Manufactured,"*
- *AI indicates the test setup is "As Installed,"*
- *AU indicates the test setup is "As Used,"*

yyy indicates the control level of tracer gas established by the test in ppm. As an example: A test rating of AU 0.500 would indicate that the fume hood controls the leakage into the laboratory to 0.500 ppm at the mannequin's sensing point with a tracer gas release rate of 4.0 Lpm.

The tracer gas test need only be performed once per hood. However, if employers have chosen to perform the tracer gas test on subsequent occasions, it is the most recent record of test results and test configuration that shall be maintained pursuant to subsection (c)(2)(C).

(C) The record of the most recent tracer gas test results and the "as used" test configuration shall be maintained as long as the automatic system is operable and thereafter for five years.

(d) Operation:

Mechanical ventilation shall remain in operation at all times when hoods are in use and for a sufficient time thereafter to clear hoods of airborne hazardous substances. When mechanical ventilation is not in operation, hazardous substances in the hood shall be covered or capped off.

(e) Special Requirements:

(1) The face velocity required by subsection (c) should be obtainable with the movable sashes fully opened. Minimum acceptable sash opening height for certification shall not be less than 18". Where the required velocity can only be obtained by partly closing the sash, the sash and/or jamb shall be marked to show the maximum opening at which the hood face velocity will meet the requirements of subsection (c). Any hood failing to meet requirements of subsection (c) and this paragraph shall be considered deficient in airflow and shall be posted with placards, plainly visible, which prohibit use of hazardous substances within the hood.

(2) When flammable gases or liquids are used, or when combustible liquids are heated above their flashpoints, hoods shall be designed, constructed, and installed so that hood openings at all sash positions provide sufficient airflow to prevent ignitable concentrations. Concentrations in the duct shall not exceed 20% of the lower explosive limits.

(3) In addition to being tested as required by Section 5143(a)(5), hoods shall meet the following requirements:

(A) Hoods shall be equipped with a quantitative airflow monitor that continuously indicates whether air is flowing into the exhaust system during operation. The quantitative airflow monitor shall measure either the exact rate of inward airflow or the relative amount of inward airflow. Examples of acceptable devices that measure the relative amount of inward airflow include: (i) Diaphragm pressure gauges, (ii) inclined manometers, and (iii) vane gauges. The requirement for a quantitative airflow monitor may also be met by an electronic airflow alarm system if the system provides an audible or visual alarm when the airflow decreases to less than 80% of the airflow required by subsection (c).

(**B) Qualitative airflow measurements** that indicate the ability of the hood to maintain an inward airflow at all openings of the hood as required by subsection (c)(1) shall be demonstrated using smoke tubes or other suitable qualitative methods. This demonstration shall be performed:

1. Upon initial installation;

2. On an annual basis;

Exception to Subsection (3)(B)2.: The frequency of the tests may be reduced to every two years if a calibration and maintenance program is in place for the quantitative airflow monitor or alarm system;

3. After repairs or renovations of the hood or the ventilation system in that part of the facility where the hood is located; or

4. After the addition of large equipment into the hood.

(4) **Exhaust stacks** shall be located in such a manner with respect to air intakes as to preclude the recirculation of laboratory-type hood emissions within a building. To protect employees on the roof, any one of the follow methods shall be utilized:
(A) Chemical treatment, absorption on activated charcoal, or scrubbers;

(B) Dilution of toxic materials below prescribed exposure limits prior to discharge;

(C) Locked gates, doors, or other equivalent means acceptable to the division that prevent employee access to exhaust stack discharge areas while hoods are in operation unless personnel are provided with appropriate respirators and other personal protection; or

(D) Exhaust stacks extending at least 10 feet above the roof and discharging vertically upward. Where rain protection is desired, high velocity discharge or concentric-duct, self-draining stacks or equivalent may be used. Rain caps, screens, backdraft dampers and any other features that divert or restrict the exhaust toward the roof are prohibited.

(5) Where emissions from the exhaust stack are likely to cause harmful exposure to employees, an effective air cleaning system shall be provided. Where virulent pathogens are likely to be released in the hood, incinerators or equally effective means of disposal shall be provided in the exhaust system to prevent employee exposure. See Section 5154.2 for requirements for biological safety cabinets.

(6) Blowers exhausting laboratory-type hoods in which hazardous substances are used shall be mounted outside the building or in service rooms outside the working area. For hoods with single, independent exhaust systems, blowers may be mounted inside the building provided that corrosion-resistant, sealed-joint ductwork is used. Exhaust ducts serving fume hoods shall be always maintained under negative pressure. (i.e., exhaust blowers shall be located on the roof of buildings)

(7) When perchloric acid is evaporated in laboratory-type hoods, the provisions of Section 5143(a)(4) shall apply. The materials of construction shall be inert, smooth, and nonabsorbent. Organic polymers shall not be used except for inert fluoropolymers, such as polytetrafluoroethylene [PTFE] and tetrafluoroethylene-hexafluoropropylene copolymer [Teflon FEP], or similar nonreactive material. The hood and exhaust system shall be washed down with deionized water for decontamination and prior to opening for maintenance.

Exception: Portable laboratory scrubbing apparatus for perchloric acid digestions may be used in lieu of the special requirements of this paragraph.

(f) Operator Qualifications:
The employer shall ensure that employees who use laboratory-type hoods are trained to:
(1) Use the hood and its features safely;

(2) Determine the date of the last performance test conducted pursuant to subsection (c)(2)(B) and if the hood performance met the requirements of this section;

(3) Understand the general hood purpose, airflow characteristics, and potential for turbulent airflow and escape of hazardous substances from the hood; and,

(4) Know where the quantitative airflow monitor or alarm system is located on the hood and how it is used to indicate an inward airflow during hood operation.

(g) Stacks: The fume exhaust is generally blown out of a stack. The design of the stack and the velocity of the discharge is selected to disperse all contaminants so that they are sufficiently diluted by the time they are near any occupants. For contaminants like radio isotopes for which there is no acceptable level of dilution, the exhaust system typically has some form of filtration that captures the particles of concern. On general lab exhaust there is typically an inlet bypass damper on the exhaust fan that modulates to keep a constant volume of exhaust moving at the stacks. Using multiple stacks in parallel one can stage off stacks and fans to save more energy

Energy conservation considerations:

(h) Airflow Reduction Requirements: Unless noted otherwise, fume hoods shall be designed and installed to work in VAV mode. Paragraph §140.9(c)1 requires that all laboratory exhaust with minimum circulation rates of 10 air changes per hour (ACH) or lower shall be designed for variable-volume control on the supply, fume exhaust, and general exhaust. This requirement will enable the system to reduce zone exhaust and makeup airflow rates to the minimum allowed for ventilation or to maintain the required differential pressure for the zone.

An exception is provided for laboratory exhaust systems where constant volume is required by code, the approving authority, or the facility environmental health and safety (EH&S) division:
[Exception 1 to §140.9(c)1]. Examples include hoods using perchloric acid, hoods with radio isotopes, and exhaust systems conveying dust or vapors that need a minimum velocity for containment.
[Exception 2 to §140.9(c)1]. A second exception is provided for new zones added to an existing constant volume exhaust system unless prescribed by Caltech PD&C Mechanical Engineer or project manager.
[Exception 3 to §140.9(c)1]. Laboratory volume is great enough that the ventilation rate is driven by a certain minimum number of air changes per hours, ACH.

- The energy and demand savings depend strongly characteristics of the facility, including: 1. Ratio of lab to non-lab space. 2. Minimum airflow required by code or the facility EH&S department. These range from 4 to 18 ACH or higher

(i) Fume Hood Automatic Sash Closure: Fume hood intense laboratories with VAV HVAC systems and vertical fume hood sashes are prescriptively required to install automatic sash closure systems. This measure saves energy by reducing laboratory exhaust air and makeup air conditioning. For this measure, fume hood intense means the air change rate of the space is driven by the fume hood exhaust, not minimum ventilation requirements. See Table below, which specifies fume hood intensity by linear hood density and minimum ventilation air change rate. The Energy Standards and best engineering practices dictate several necessary components to this type of system:

1) Zone Presence Sensors: Each sash closure system must have a dedicated zone presence sensor that detects people near the fume hood. Sensor should not be triggered by movement in adjacent zones.
2) Sash should automatically close within 5 minutes of sensing no presence within the fume hood zone.

3) Sash closure system safeguards: a) Sash automatic closing should stop when no more than 10 lbs is detected. Bb) Sash should have obstruction sensors that can detect obstructions, including transparent materials such as glassware.

4) Sash closure system must be configurable in a manual open mode. 1. Manual open mode requires user input (push button, pedal, etc.) to open the sash and will not open automatically from presence detection

5) If the labs are deemed to be fume hood intensive according to table below for the corresponding minimum ACH, they are required to have sash closing controls on any vertical sash hoods. Automatic sash closing controls are required for any vertical-only hoods in fume hood intensive spaces in variable-volume laboratories.

(j) Fume Hood Intensive Laboratory Table:

Occupied Minimum Ventilation ACH	≤ 4	> 4 and ≤ 6	> 6 and ≤ 8	> 8 and ≤ 10	> 10 and ≤ 12	> 12 and ≤ 14
Hood Density (linear feet per 10,000 cubic feet of laboratory space)	≥ 6	≥8	≥ 10	≥ 12	≥ 14	≥ 16

APPENDIX XXIV – CONTROL SPECIFICATIONS

See link: 2021 v5.3 Control Specifications

APPENDIX XXV – ALARMS and POINT NAMING STANDARDS

See link: ALARMS AND POINT NAMING STANDARDS

APPENDIX XXVI – EXTERIOR SIGNAGE GUIDELINES

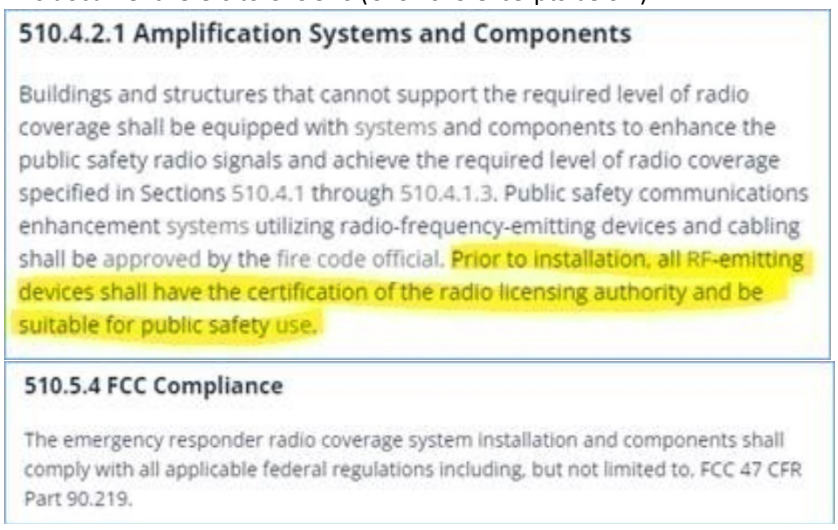
See link: EXTERIOR SIGNAGE GUIDELINES

APPENDIX XXVII – DAS ERRCS Requirements

Note: This information is provided for reference only. Design Team to obtain and comply with latest regulations. For complete reference documentation base on which the summary below is provided, see the "2024 DAS ERRCS Supplement Documents" on the Caltech design guidelines website. These documents were obtained in 2023.

Reference summary:
Based on feedback from COMSEC, DAS systems in Pasadena are required to comply with the City of Glendale's ERRCS requirements. Pasadena ERRCS systems use radio frequencies for which Glendale is the FCC Licensee. Non-licensees (Caltech and its contractors or authorized agents) are required to obtain express consent from licensees to signal-boost FCC-governed frequencies, and the licensee (Glendale) is to maintain control over this signal-boosting per the FCC. Hence Glendale's ERRCS requirements are included here for reference.

A. Pasadena Requirements: "Technical Specifications Related to ERRCS City of Pasadena Fire Department." This document refers to CFC 510 (CFC 2019 excerpts below).



510.4.2.1 Amplification Systems and Components

Buildings and structures that cannot support the required level of radio coverage shall be equipped with systems and components to enhance the public safety radio signals and achieve the required level of radio coverage specified in Sections 510.4.1 through 510.4.1.3. Public safety communications enhancement systems utilizing radio-frequency-emitting devices and cabling shall be approved by the fire code official. Prior to installation, all RF-emitting devices shall have the certification of the radio licensing authority and be suitable for public safety use.

510.5.4 FCC Compliance

The emergency responder radio coverage system installation and components shall comply with all applicable federal regulations including, but not limited to, FCC 47 CFR Part 90.219.

B. Frequencies: Glendale is the FCC Licensee for all the Pasadena ERRC frequencies. Refer to Attachment 1 for the frequencies. Licensee can be confirmed in the FCC database: https://wireless2.fcc.gov/UlsApp/UlsSearch/searchAdvanced.jsp

C. CFC 510 above refers to FCC 47 CFR Part 90.219.

FCC 47 CFR Part 90.219 (as of 1/1/19): requires licensees (Glendale in our case) to maintain a reasonable level of control over use of signal boosters across their frequencies and requires non-licensees (Pasadena and Berg/HP/Caltech) to obtain the express consent of the licensee.

(b) ***Authority to operate.*** PLMRS licensees for stations operating on assigned channels higher than 150 MHz may operate signal boosters, limited to the service band for which they are authorized, as needed anywhere within the PLMRS stations' service contour, but may not extend the stations' service contour.

(1) PLMRS licensees may also consent to operation of signal boosters by non-licensees (such as a building owner or a signal booster installation contractor) within their service contour and across their applicable frequencies, but must maintain a reasonable level of control over these operations in order to resolve interference problems.

(i) Non-licensees seeking to operate signal boosters must obtain the express consent of the licensee(s) of the frequencies for which the device or system is intended to amplify. The consent must be maintained in a recordable format that can be presented to an FCC representative or other relevant licensee investigating interference.

D. Glendale Requirements – See Attachment 3 City of Glendale ERRCS Installation and Operation Guideline

a. Antenna Density Requirement excerpt

12. **Antenna Density**
    A. ERRCS shall be designed with a sufficient density of indoor service antennas to minimize the required amplifier gain and the near-far effect. Indoor (service) antennas should be spaced no more than 50 feet apart within occupied areas, and no more than 80 feet apart in open areas such as parking garages, auditoriums, conference centers, and ballrooms.

b. Remote Control and Monitoring excerpt

E. Remote Control and Monitoring
- i. All new and existing ERRCS shall be equipped to permit the FCC License Holder or its designee to remotely monitor and control the bidirectional amplifier (BDA) or other RF emitting device(s) pursuant to Title 47 CFR §90.219.
  - a. A 100 Mbps or faster Ethernet connection with active connection to the Internet and a DHCP assigned IP address shall be provided within 18 inches of the BDA.
  - b. A monitoring and remote-control component specified by the FCC License Holder shall be installed in a NEMA-4 or 4X, enclosure and shall provide monitoring of alarms from, and secure remote connectivity to, the BDA(s), fiber master or headend, and associated power supply(s).
  - c. The monitoring and control component shall be powered by the BDA primary and secondary (backup) power supplies.
- ii. It is the responsibility of the building owner to provide remote monitoring and control capability for the FCC License Holder or its designee.

APPENDIX XXVIII – Fume Hood Selection Features

The following features should be considered when selecting a fume hood during the planning and design phase and are presented as reference only.

1. Fume hood dimensions: Length/width/height
2. Availability of exhaust air and makeup air requirements
1. Type:
   a. Constant Air Volume (CAV)
      1) Refer to current edition of the California Energy Code for additional restrictions.

   b. Variable Air Volume (VAV)
      1) Refer to current edition of the California Energy Code for additional requirements.

3. **Bypass types:**
   a. (CAV) with standard bypass
   b. (VAV) with restricted bypass
   c. Auxiliary or add-in bypass for areas with limited make-up air availability
4. Pressure-dependent versus pressure-independent air flow regulation.
5. Type of pressure-independent air flow regulation:
   a. Conventional Terminal Units
   b. High Accuracy Terminal Units (AccuValve, Etc).
6. Front Sash Configuration:
   a. **Vertical Sash:** Slides straight up and down; standard choice providing wide workspace entry.
   b. **Horizontal Sash:** Slides side-to-side; maximizes containment and lowers the open face area to save energy.
   c. **Combination Sash:** Moves both horizontally and vertically to offer optimal setup flexibility.
7. Sash material selection:
   a. Polycarbonate
   b. Tempered glass
   c. Laminated safety glass
8. Sash frame:
   a. Frameless
   b. Powder coated steel
   c. Type 304L stainless steel
   d. Type 316L stainless steel
9. Interior liner material
   a. 316L stainless steel
   b. 304L stainless steel
   c. Chemglass (fiberglass reinforced polyester)
   d. Phenolic Resin
10. **Counterbalance Controls:** Mechanism for smooth sash adjustments, such as a chain-and-sprocket drive, which holds its position safely without drifting

11. Occupancy sensor requirements
12. Work surface material requirements
13. Automatic sash closer on VAV fume hoods, where required.
14. Flammable / solvent storage base cabinet (non-ventilated)
15. Acid storage base cabinet requirements
16. Vacuum pump base cabinet requirements
17. Vacuum pump base cabinet requires cooling fan, Line voltage power, toggle switch or a thermostatic switch for the cooling fan with pilot light, Ventilation duct for the vacuum pump effluents, vacuum pump tray on rollers or casters, acoustical lining for sound dampening.
18. Self-closing base cabinet doors.
19. Cup sink and drainpipe. (Industrial cold water or deionized water)
20. **Integrated Utilities:** Pre-plumbed fixtures for localized access to DI water, ICW, gas lines, vacuum systems
21. **Electrical outlets**: Type and quantity
    a. Colors: red, black, ivory, white, grey
    b. 120 VAC GFCI, 20 Amp
22. **Utility gases:** associated valve types and need for local pressure regulators.
23. Dedicated isolation valves are required on top of fume hoods for each utility (Provided by the Plumbing Contractor)
24. **ASHRAE 110 certification execution environment**. ASHRAE 110 protocols classify testing into three distinct operational phases:
    a. AM (As Manufactured): Performed in a factory test room to establish peak design capabilities before shipment
    b. AI (As Installed): Conducted immediately after placement in the laboratory but before chemicals are introduced to verify that the facility's localized HVAC dynamics have not compromised performance.
    c. AU (As Used): Conducted under everyday real-world conditions with interior lab equipment, mock containers, and active walk-by cross-drafts present.
25. **Regulatory Frequency Requirements:**
    a. Annual Recertification: Legal regulations under CCR 5154.1and ANSI/ASSP Z9.5 dictate that active chemical fume hood flow rates must be re-certified at least on an annual basis.
    b. If the lab is using chemicals covered under CCR 5209, then the recertification of the flow rate is every six (6) months and the required flow rate of an average of 150 fpm with a minimum of 125 fpm.
    c. **Event-Driven Recertification:** Immediate comprehensive testing is required following initial field installation, heavy physical relocation, or any operational modifications made to the facility supply/exhaust air ducts and distribution systems.
26. **Airflow Monitors:** Visual or acoustic low-flow alarms that alert laboratory personnel instantly if face velocity drops below legal limits.

27. **Sash Management Alarms:** Alerts that prompt users to shut the front glass whenever the hood is unattended, preserving room climate control.

28. **Material Compatibility for Liners and baffle Types.**

    a. Poly Resin / Epoxy Resin: Standard for broad chemical use and high stain resistance.

    b. Polypropylene: Excellent for handling concentrated, highly corrosive mineral acids.

    c. 316L Stainless Steel: Mandatory for radiochemistry or perchloric acid work to withstand washdowns and prevent dangerous salt crystallization

29. **Ductwork material type:** 316L stainless steel for all applications except for Perchloric Acid fume hoods that require Unplasticized PVC. It is inherently non-reactive, resistant to chemical corrosion, and allows for smooth, easy-to-flush vertical runs.

30. **Work Surface:** Type 316L Stainless Steel is required, ideally with coved (rounded) corners and a continuously welded, dished surface to contain spills and wash-down water.

31. **Perchloric fume hoods:** A dedicated, built-in wash-down system is mandatory for perchloric hoods, regardless of the material. This ensures all ductwork and internal surfaces are regularly rinsed to dissolve and remove any explosive perchlorate deposits. A dedicated, built-in wash-down system is mandatory for perchloric hoods, regardless of the material. This ensures all ductwork and internal surfaces are regularly rinsed to dissolve and remove any explosive perchlorate deposits. Provide deionized water for the wash-down cycle.

32. Internal lattice support types and materials

33. ADA compatibility features

APPENDIX XXIX – Office & Lab Demo Protocol for Materials Recycling

PM + No Contractor	PM + General Contractor
1. PM notifies shops of materials they can reuse 2. Recycling & Materials Coordinator, Recycling Lead, and Transportation Supervisor conduct walk of building to identify materials for reuse/recycling 3. Transportation salvages “sellable” materials for sale to be held in CES 4. Transportation notifies campus users of reuse opportunities 5. Transportation also stages materials that would be landfilled and are not reusable on campus in CES to be given to outside company 6. Transportation moves recyclable materials to Holliston Recycling Yard/Amazon Yard for recycling 7. Transportation landfills materials that cannot be reused, recycled, or stored	1. PM notifies shops of materials they can reuse 2. Recycling & Materials Coordinator, Recycling Lead, and Transportation Supervisor conduct walk before contractor removes materials, identifying (from most preferable to least preferable): • Items that can be reused on campus • Items Caltech can store in CES for resale • Items Caltech can have picked up from outside company • Items Caltech can recycle • Items that will be landfilled 3. Transportation takes materials to proper area (see 3–7 at left) 4. Contractor then removes waste with partnering hauler/trash company diverting waste and providing report