

THE RALPH M. PARSONS COMPANY

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Contract PP150969
Control No. 950213-0

received
FEB 13 1995

February 13, 1995

Mr. Fred Asiri
Technical Representative
Caltech -- LIGO Project
East Bridge Lab
Mail Stop 102-33
Pasadena, CA 91125

Subject: Transmittal of Draft Design Configuration Control Document

Dear Fred,

We are transmitting the following items to you:

Item	Copies	Dated	Description
1	3	2/13/95	Draft Design Configuration Control Document

These items are transmitted as checked below:

- | | | |
|--|--|---|
| <input type="checkbox"/> For approval | <input type="checkbox"/> For your signature | <input type="checkbox"/> Resubmit ___ copies for review |
| <input type="checkbox"/> For your use | <input type="checkbox"/> Make changes noted | <input type="checkbox"/> Submit ___ copies for distribution |
| <input type="checkbox"/> As requested | <input type="checkbox"/> Revise and resubmit | <input type="checkbox"/> Return ___ corrected prints |
| <input checked="" type="checkbox"/> For review and comment | <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> For bid due _____, 1995 | | <input type="checkbox"/> Returned after loan to us |
| <input type="checkbox"/> | | |

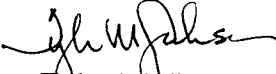
Transmitted with this letter is the Subject document. As you fully understand, this is a growing document and will be updated and resubmitted as required. The next submittal will be 15 days after receipt of LIGO's review comments.

We are also transmitting a diskette containing a MS Word file that contains a suggested format for inputting and returning your review comments. This approach has been used successfully with other Clients for similar projects where reviewers are geographically scattered. This approach will assist with many problems in a typical review process. Jeff Hermann will

provide additional clarification of this method when we next meet. Also attached to this transmittal is a hard copy of the review comments form, and an example page from a previous project.

Jeff Hermann will contact you to discuss possible time, place, and format of a presentation on the DCCD. We anticipate receipt of your comments by March 6, 1995 and will schedule a meeting to discuss disposition of these comments.

Sincerely,



Tyler M. Jackson, PE
Project Manager

TJ/JH/jh

Enclosure: Draft DCCD (1 Original, 3 Copies)
Diskette Containing MS Word Comments File

cc: Administration Files
Jeff Hermann
Tim Melott

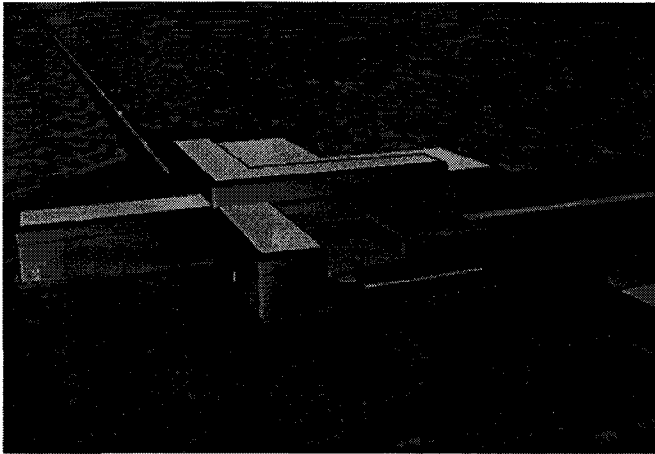
File: 5.2.1

100% Review Comments

Payload Preparation Facility

Item	Document	Reviewer	Comment	Code	Discipline -- Response
1	ST-025	D.A.Zanese	Drawing shows a "DS-18 Platform Framing Plan", but does not say where frame is located. Provide reference back to mechanical drawing where duct and support.	A	ST -- We will comply.
2	ST-025	S.Staub D.A.Zanese	"DS-18 Platform Framing Plan" of this drawing calls for expansion anchors. Per specification 13080, Section 3.6, no expansion anchors are to be used to resist seismic or vibratory loads (unless test data are provided to verify the adequacy of the specific anchor and application) . Therefore , remove expansion anchors in Section B and Details 4 . Support must be designed using an importance factor of 1.5 in accordance with FDC paragraph 3.5.1.4.d and UBC section 2336.	AWC	ST --Typically this is best handled by requesting the ICBO approvals be submitted. Call-out for expansion anchors will be removed. Will use drilled holes and non-shrink grout for anchorage.
3	ST-027	D.A.Zanese	Detail 1 presents enlarging of footing at 12 and D.1, but it only presents specific rebar details of footing enlarging in north/south direction. It does not even say "typical" to apply rebar details -- adding of dowels, etc -- to the east/west footing enlarging. Detail 1 and Section A need to be revised to provide specific rebar details of footing enlarging in both north/south and east/west direction.	A	ST -- We will add "all around" note to Section A.
4	ST-027	D.A.Zanese	To be consistent with drawing ST-003, Section A should call out "3/4 inch joint filler" between two footings.	A	ST -- We will call out filler.
5	ST-027	D.A.Zanese	Section B presently refers to "Centerline of Crane". It should instead say "Centerline of Sliding Door".	A	ST -- We will correct.
6	ST-027	D.A.Zanese	Section B is taken in EIR and is cross section of grade beam added for door rail. My information is that access trench shown in this section is filled in, yet section shows open trench. Revise section to show filled in trench with slab across top (for reference, AR-002 also indicates trench is covered over, as it depicts "existing slab over trench").	A	ST -- We will show existing slab over trench.
7	ST-102	D.A.Zanese	Frame elevation at Column Line D.1 should show door frame between column lines 9 and 10 is removed.	A	ST -- We will add door.
8	Volume 1 Calculations (Structural)	D.A.Zanese	Page 31 uses factor of 10 percent in addressing impact load consistent with AISC. However, per AFM 88-3, Chapter 1, a factor of 25 percent should be used for impact. Revise calc (and design if necessary) to reflect impact value of 25%.	A	ST --

Codes: A--Accept; AI--Action Item; D--Duplicate; R--Reject; C--Clarification Needed; W--Withdraw; AWC--Accepted with Comment; Info--Information Provided; AR--Architect; CE--Civil; CR--Crane; EE--Electrical; MA--Material Applications; MS--Mechanical Specialties; MU--HVAC; PL--Plumbing; ST--Structural; PM--Project Manager



Design Configuration Control Document

Draft

February 13, 1995

LIGO
Laser Interferometer Gravity Wave Observatory
California Institute of Technology
The Ralph M. Parsons Company
Contract Number: PP150969

LIGO Document _____
CDRL Number 06
DRD Number 03

APPROVAL STATUS

YES NO NOT REQUIRED

Project Manager, Parsons

Technical Representative, Caltech

Parsons-LIGO

Laser Interferometer Gravity Wave Observatory

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1. Scope

The purpose of this document is to establish baseline design criteria for the Laser Interferometer Gravitational-Wave Observatory (LIGO) Facility Design. The baseline design criteria is developed from the LIGO Facility Request for Proposal No. YM 193, the LIGO Vacuum Equipment Request for Proposal No. MH 178, our understanding of LIGO Project needs, and industry standard design and construction practices that will meet or exceed these needs.

This document serves as a facility design criteria from which the configuration of the facility will evolve. As it evolves, this document will be updated. This document will continue to be the source for configuration control information for the direction of the design process. It is also the baseline for the design effort.

By reference, criteria provided in the LIGO Facility Request for Proposal Number YM 193, and the LIGO Vacuum Equipment Request for Proposal Number MH 178 constitute an element of this document and are therefore considered an element of the Facility's controlled design configuration. Concept strawman design approaches presented in these RFPs are not an element of the controlled design configuration; however, the layouts of the Vacuum Equipment in the LVEAs are considered a controlled design configuration.

2. Facility Overview

The LIGO project is a pioneering effort to design and construct a novel scientific facility - a gravitational-wave observatory -- that will open a new observational window on the universe.

LIGO will consist of two observatory facilities located at Hanford, Washington, and Livingston, Louisiana. These facilities will incorporate L-shaped vacuum systems with arms of 4 km length. The vacuum systems (by others) will house laser interferometer detectors sensitive to gravitational waves from astrophysical sources. Initial detector sensitivity will detect strains as small as 10^{-22} ; the existing 1/100 scale prototype has measured strains to 10^{-17} . Correlation of data from interferometers at the two sites will allow identification of gravitational waves, their sources and origin in space. LIGO will become the first part of a planned worldwide network of gravitational-wave detectors coordinated to operate as a single observatory complex. Current plans are to begin observatory operations by the year 2000.

Constructed facilities at each site include the main corner station, with the large laser and vacuum equipment area, end and corner buildings on each beam tube leg, and a central plant. Building work includes power distribution, lighting, security systems, fire protection, communications, control system, access platforms, clean rooms, cranes, heating ventilating and air conditioning, and cable raceways. Each site will have two beam tube enclosure structures, each 4 km long. Sitework for the virgin sites includes site

grading, drainage, roads, parking, landscaping, water supply developed from wells, sanitary facilities, waste water treatment and disposal and power distribution from area utilities.

Facility design will address special building requirements for the laser and vacuum equipment areas located at the corner, mid and end stations. Vibration isolation and reduction is required in order that transmitted vibration energy is no more than a factor of two above natural ambient levels. Both sites were selected based on their low ambient background noise and vibration levels. This requires seismic mass type foundations for critical scientific equipment and separate foundations and remote locations for vibration producing equipment and occupancy. Laser and vacuum equipment will be located in large open space of high volume (3.5 million cubic feet) designed as a clean room to Class 50,000. Smaller support areas for scientific equipment will require clean room conditions to Class 1000 or better. The laser interferometer detector is sensitive to EMI effects and will require special design for power, lighting, and control circuits to minimize disturbances. The laser interferometer detector is also sensitive to local gravity field gradients which requires special provisions for people and equipment movements.

3. Functional Description

3.1 Laser and Vacuum Equipment Area (LVEA)

This area is designed to house the high precision, sensitive interferometer components. The interferometers require a clean controlled environment with a minimum of disturbance from acoustic noise, ground vibrations, electromagnetic interference and other localized disturbances. Each interferometer uses one or more high power lasers which will be located within this area. Power and cooling must be provided for these lasers. The electro-optic interferometer components are contained within a high vacuum envelope generally referred to as the "vacuum equipment".

The vacuum equipment comprises a network of chambers, which house the sensitive interferometer components, and interconnecting beam-tubes which transmit laser beams between the chambers. High vacuum gate valves are provided between segments of the interconnecting tubing to isolate different portions of the vacuum system for diagnostics, maintenance, or upgrades while other portions remain operable.

Re-locatable vacuum pumps are deployed where needed by overhead crane and coupled locally to valved pumpout ports for initial pumpdown. Electrical power, compressed air, monitor/control system, and pump exhaust lines are provided near the pumpout ports. Stationary high-vacuum ion pumps attached to the individual chambers contend with normal outgassing, porosity and leakage. Liquid nitrogen (LN₂) pumps at the ends of the adjacent beam-tube modules provide additional capacity for removing condensable gases.

The vent/purge subsystem generates and distributes filtered, dry air for backfilling chambers when they are to be opened and provides internal filtered air showers to maintain cleanliness while working inside the chambers. A bakeout subsystem, comprising of relocatable heaters, insulation and power connections, allows optional vacuum baking of individual valved-off sections of the vacuum equipment. This permits removal of contaminants and reduction of outgassing when required.

In addition to lasers and vacuum equipment, this area contains the electronics racks and cabling for the interferometers. The racks house the servo loop electronics, control and monitoring electronics, and computer networking electronics. Cable raceways will each serve each chamber, pump or valve location.

3.2 Operation Support Building (OSB)

3.2.1 Staff Offices, Lobby, and Visitor Accommodations

This area includes offices and common areas such as rest rooms, break room, conference room, suitable for a permanent staff of 21 employees. This staff will consist of 8 professionals and 13 technicians/operators. Approximately 15 visiting scientists and interns are anticipated during the year, each with a stay of one week to six months. Other visitors will include tour groups of students, educators, scientists, and dignitaries. The facility entrance for employees, users, and visitors is through a lobby and controlled by a receptionist/secretary area. The conference room and all offices have provisions for computer networking.

3.2.2 Control Room

The control room is the operational center of the facility. It will provide an office quality environment for the operations crew. Physical plant control and monitoring is executed from this room. The control room equipment consists mainly of desktop computing workstations and rack mounted electronics. This room also provides space for the central monitoring panels of facility services such as fire protection, personnel access control, and building surveillance via a low-light level closed circuit television system.

3.2.3 Computer and Data Archives Room

This room houses rack-mounted computing equipment and peripherals (disk and tape drives, etc.) as well as storage cabinets for magnetic tapes. Portions of this area will have a access flooring to allow for easy cabling. The room will be provided with fire suppression equipment.

3.2.4 Change/Smock Room

All personnel will enter the LVEA via this room. This room will contain small lockers and benches to facilitate the gowning-up process prior to entering the LVEA.

3.2.5 Experiment Equipment Area

This room will house equipment being developed for use in association with the LIGO experiments. It will also serve as the area where new equipment for use with or as replacements for equipment used in LIGO is assembled. This room will contain a small laser, vacuum chambers for performance testing, and a vacuum bakeout chamber.

3.2.6 Testing Area

A testing area is provide for setup and checkout of interferometer components before installing them into the vacuum equipment. This room will contain a small laser, vacuum chambers for performance testing, and a vacuum bakeout chamber.

3.2.7 Mechanical and Electronic Shop

These shops are provided for maintaining and repairing interferometer and facility equipment. The electronics shop contains electronic service instrumentation and calibration equipment for vacuum instrumentation, auxiliary physics monitoring instrumentation, computers, and interferometer electronics. The mechanical shop contains small scale machining and welding equipment for maintaining or modifying interferometer components and vacuum chambers.

3.2.8 Active Storage and Long Term Storage

These areas will be used to store the parts and components integral to the maintenance of the facility and the equipment.

3.2.9 Receiving and Shipping, and Inspection Area,

Equipment that arrives at the LIGO facility will be processed through this area in a manner which ensures the integrity of the clean environments. Packages that arrive at the loading dock will be cleaned externally before being moved into the receiving and shipping area. There, they are unpacked from the outer shipping container and moved to the inspection area, where the inner packaging is removed and the contents are inspected.

3.2.10 Cleaning Area

Equipment destined for the vacuum equipment area is moved from the Inspection Area through the Cleaning Area for removal of dust or contamination. The doors connecting through this area will be opened one at a time to prevent outside dust or particulate contamination riding on packaging from reaching the clean LVEA.

3.2.11 Cleanroom

This room is a Class 1000 cleanroom with ceiling supply and wall return air flow. The room will be used for the installation of the laser components into the argon-ion lasers and the test mass chambers. It will also contain Class 100 laminar flow work benches. This room will also be used to setup any developmental devices needed in association with the LIGO project. The cleanroom will be accessed through an air-shower type airlock anteroom to accommodate the large lasers and chambers.

3.3 Mechanical/Utility Building

This building provides space for equipment such as heating, ventilation, and air conditioning (HVAC), and other mechanical and electrical equipment associated with the facility operations. The Mechanical/Utility Building is vibrationally isolated from the LVEA and is serviced by a remotely located chiller plant to minimize vibration transfer to the LVEA. Air handling units are designed for minimum induced vibration and acoustic noise. Cooling for the lasers is provided by individual closed-loop de-ionized water cooling systems with heat exchangers located in the utility building and coupled to a facility chilled-water line.

3.4 Chiller Building

The corner station chilled water plant provides chilled water to the HVAC systems, and the closed loop cooling systems for the lasers. The plant utilizes air cooled refrigeration units. The chilled water plant is remotely located from the corner stations to minimize transmitted vibration and is isolated acoustically to minimize acoustic energy transmission to the LVEA.

3.5 Mid Station and End Station

The buildings for the end stations at both sites and the mid stations at the Washington site are of similar design, but differ in their vacuum equipment layout. The functional requirements and designs are similar to those of the corner stations, except that the vacuum equipment in these stations is much simpler and there is no need for personnel offices. These stations include a vacuum equipment area, a support services area, a utility room, and a remote chilled water plant. Access to the buildings and the vacuum chamber

areas is controlled and monitored from the corner station control room by the facility operator.

3.5.1 Vacuum Equipment Areas

The design and construction approaches of vacuum equipment area are similar to those used in the LVEA in the corner station. These areas contain vacuum chambers, pumps, and valves which are serviced by an overhead bridge crane with a minimum _____ foot hook height. It also encloses electronics racks and associated cabling for control and data acquisition.

3.5.2 Operation Support Area

The design and construction approaches of the Operation Support Area are the same as those of the corner station. It includes space for interferometer and facility electronics equipment, areas for unpacking, inspection, and cleaning of interferometer and vacuum equipment. It also includes a small work area for maintenance and a Class 1000 cleanroom for servicing interferometer components and optics.

3.5.3 Utility Area

An attached utility room, with separate foundation for vibration control, houses mechanical (i.e., HVAC air handler units, etc.), and electrical (i.e, motor control centers, etc.). Chillers are housed in a separate and remote plant.

3.5.4 Chilled Water Plant

This plant is separate from the mid and end stations and is of similar design to the corner station plant. Chilled water will be required for the HVAC system only since there are no high-power lasers in these stations.

3.6 Midpoint Pump Stations

This station is for the Louisiana site only. It replaces the Mid Station Vacuum Equipment area and will contain beam tube rough vacuum pumps. In addition to the pumps, it will house associated mechanical and electrical equipment.

3.7 Beam Tube Foundation and Enclosure

The beam tube enclosures at each site are made up of four identical 2 kilometer long modules. The beam tube enclosure protects the high-vacuum beam tube walls from vibration induced by wind. In addition, it protects the tube walls from mechanical impacts which could release bursts of gas into the interferometer beams, thereby contributing

noise. The enclosure provides an moderate amount of thermal stability for the beam tubes, reducing the variation in residual gas pressure. It also provides protection against damage to the beam tubes from stray bullets. A proposed configuration is shown in the Figure 3.7-1.

The foundation at the beam support must be constructed to a vertical tolerance of $\pm 1/2$ inch between the successive supports (about 65 ft apart). Beam tube supports will be attached to the foundation with anchor bolts. The foundation must be designed to minimize settlement and to take static and vacuum related loading of the beam tubes and their various components. See Section 6.3.2.9 for additional criteria on this subject.

The beam tube enclosures are not normally occupied. The enclosure configuration provides adequate room for access to repair leaks, adjust alignment of the beam tube and conduct occasional beam tube bakeouts. Entries to the beam tube enclosure are required at about 250 meter intervals for installing and servicing the future ion getter pumps. The enclosure provides space for internal cableways for distribution of signal and power cables. Minimal permanent lighting is required. Utility outlets are provided at the 250 meter entries. The foundation is transversly sloped to drain accumulated water from the floor of the beam tube enclosure.

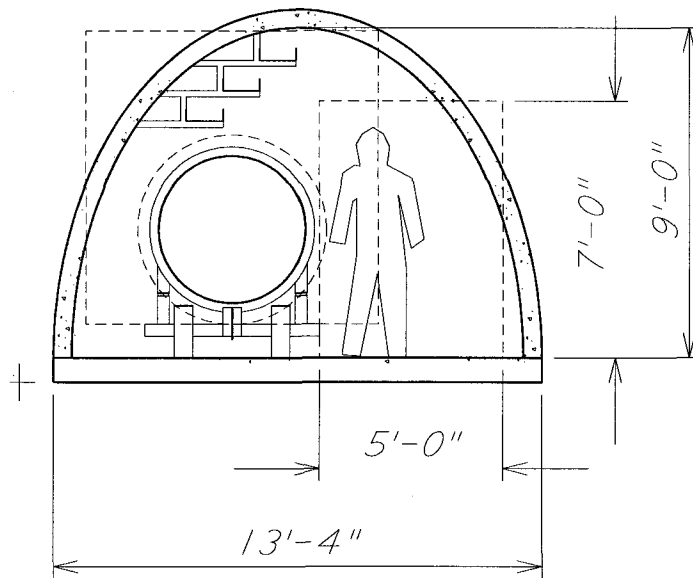


Figure 3.7-1

Potential growth of fungi at the Louisiana site due to water intrusion is a serious consideration. Dehumidification may be required to control the growth.

4. Growth and Flexibility

4.1.1 Laser and Vacuum Equipment Area

The vacuum equipment is of a modular design to permit phased expansion. The initial installation at Hanford will serve two interferometers but will be expandable to a total capacity of six by addition of chamber modules at the end, mid, and corner stations. At Livingston, one interferometer is planned initially with capacity for an additional two provided by adding chambers at the end and corner stations. Due to the cleanliness required in the vacuum equipment area and the need to maximize continuous observation capability through the life of the facility, LIGO has elected to construct stations and infrastructure consistent with the final configuration without phasing the construction.

Currently the configuration of interferometers is in an orthogonal orientation, however there is the possibility that a future interferometer may need to be angled.

5. Referenced Documents

5.1 Federal Standards

Number	Title
FEDERAL STANDARDS	
FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
FED-STD-595	Color and Number Identification
Title 29 CFR	Federal Occupational and Health
OSHA 2207	Construction Industry -- OSHA Safety and Health Standards

5.2 Military Standards

Number	Title
MILITARY STANDARDS	
MIL-STD-461D	Grounding, Bonding, and Shielding for Electronics Equipment and Facilities Applications
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
MIL-V-18436	Valves, Check: Bronze, Cast-Iron and Steel Body

5.3 Industry Standard Specifications, Codes, and Guidelines

Number	Title
Industry Standard Specifications, Codes, and Guidelines	
AASHTO	American Association of State Highway and Transportation Officials
Manual	Guide for Design of Pavement Structures
Specification	Standard Specifications for Highway Bridges
Specification	Standard Specifications for Transportation Materials
Specification	Standard Specifications for Methods of Sampling and Testing
ACCA	Air Conditioning Contractor's of America
Manual D	Equipment Selection and System Design Procedures
Manual Q	Equipment Selection and System Design Procedures for Commercial Summer and Winter Air Conditioning
ACGIH	American Conference of Governmental Industrial Hygienists
-Chapter 2	General Ventilation
ACI	American Concrete Institute
-117	Standard Specification for Tolerances for Concrete Structures and Materials
-318	Building Code Requirements for Reinforced Concrete and Commentary 60

Number	Title
Industry Standard Specifications, Codes, and Guidelines	
-530	Building Code Requirements for Concrete Masonry Structures and Commentary
AEIC	Association of Edison Illuminating Companies
-CS 5	Specification for Thermo Plastic and Cross-linked Polyethylene Insulated Shielded Power Cable Rated 5 through 69 kV
-CS 6	Specification for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 through 69 kV
-S-68-516	Ethylene Propylene Rubber Insulated Wire and Cable for Transmission and Distribution of Electrical Energy
AFBMA	Anti-Friction Bearing Manufacturers Association
-9	Load Rating and Fatigue Life for Ball Bearings
-11	Load Rating and Fatigue Life for Roller Bearings
AISC	American Institute of Steel Construction -- Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design Code of Standard Practice -- Standard Practice for Steel Buildings and Bridges
AISI	American Iron and Steel Institute
AMCA	Air Movement Control Association
-99	Standard Handbook
-211	Certified Ratings Program, Error Performance
-311	Certified Sound Ratings Program for Air Moving Devices
-500	Test Methods of Louvers, Dampers and Shutters
ANSI	American National Standards Institute
-A13.1	Scheme for the Identification of Piping Systems
-A53	Specification for Pipe Steel, Black and Hot Dipped, Zinc Coated, Welded and Seamless
-B16.3	Malleable Iron Fittings
-B16.5	Pipe Flanges and Flanged Fittings
-B16.9	Factory Made Wrought Steel Butt Welding Fittings
-B16.29	Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings
-B30.2	Safety Code for Overhead and Gantry Cranes
-B30.10	Hooks
-B31.1	Power Piping
-B32	Standard Specification for Solder Metal
-B88	Specification for Seamless Copper Water Tube
-C2	National Electrical Safety Code (NESC)
-Z358.1	Eyewashes and Showers Equipment, Emergency
-900	Test Performance of Air Filter Units
ARI	Air Conditioning and Refrigeration Institute

Number	Title
Industry Standard Specifications, Codes, and Guidelines	
-410	Force Circulation Air Cooling and Air Heating, Coils
-430	Central Station Air Handling Units
-530	Method of Measuring Sound And Vibration of Refrigerant Compressors
-540	Method for Presentation of Compressor Performance Data
ASCE	American Society of Civil Engineers
-7-88	Minimum Design Loads for Buildings and Other Structures
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
-15	Mechanical Code for Refrigeration
-52	Method of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
-34	Number Designation and Safety Classification of Refrigerants
-1989 HDBK	Fundamentals
ASME Codes	Pressure Vessel Codes, Section VIII & IX
-B16.29	Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings
-B31.1	Power Piping
-Section VIII	Rules for Construction of Pressure Vessels
-Section IX	ASME Boiler and Pressure Vessel Code
ASSE	American Society of Sanitary Engineers
-1013	Reduced Pressure Principle and Pressure
ASTM	American Society for Testing and Materials
-A36	Standard Specification for Structural Steel
-A53	Specification for Pipe, Steel, Black & Hot Dipped, Zinc Coated Welded and Seamless
-A123	Standard Specification for Zinc (Hot Dipped Galvanized) Coatings in Iron and Steel
-A126	Specification for Gray Iron Coatings for Valves, Flanges
-A278	Standard Specification for Gray Iron Castings and Pressure, Containing Parts for Temperature
-B32	Standard Specification for Solder Metal
-B88	Standard Specification for Seamless Copper Water Tube
-B280	Specification for Seamless Copper Tube and Air Conditioning and Refrigeration Field Service
-C553	Standard Specification for Mineral Fiber Blanket and Felt Insulation
-D2737	Specification for Polyethylene Plastic Tubing
-E84	Surface Burning characteristics of Building Materials

Number	Title
Industry Standard Specifications, Codes, and Guidelines	
-F50	Standard Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas Using Instruments Based Upon Light Scattering Principles
-F328	Standard Practice for Determining Counting and Sizing Accuracy of an Airborne Particle Counter Using Near-Monodisperse Spherical Particulate Materials
-F649	Standard Practice for Secondary Calibration of Airborne Particle Counter Using Comparison Procedures
AWS	American Welding Society
-A2.4	Symbols for Welding, Brazing and Nondestructive Examination
-A3.0	Standard Welding Terms and Definitions
-B2.1	Standard for Welding Procedure and Performance Qualification
-D1.1	Structural Welding Code -- Steel
-D14.1	Specification for Welding Industrial and Mill Cranes
BOCA	Building Officials and Code Administrators -- Standard for the Design and Installation of the Fire Suppression System for Life Safety
CGA	Compressed Gas Association
-4.1	Cleaning Equipment for Oxygen Service
CMAA	Crane Manufacturers Association of America
-70	Specification for Electric Overhead Traveling Cranes
CTI (TBS)	Cooling Tower Institute Standards
DHI	Door Hardware Institute
FIPS Pub 94	Guideline on Electrical Power for ADP Installations
IEEE	Institute of Electrical and Electronic Engineers
-43	Recommended Practice for Testing Insulation Resistance of Rotating Machinery
IESNA HDBK	Illuminating Engineering Society North America Handbook
IES	Institute of Environmental Sciences, Recommended Practices
-RP-CC-001	HEPA Filters
-RP-CC-006	Testing Clean Rooms
-RP-CC-013	Recommended Practice for Equipment Calibration or Validation Procedures
MSS	Manufacturers Standardization Society
-SP58	Pipe Hangers and Supports
-SP67	Butterfly Valves
-SP69	Pipe Hanger and Supports, Selection and Application
-SP70	Cast Iron Gate Valves, Flanged, and Threaded Ends
-SP72	Ball Valves with Flanged Butt Welded Ends for General Service
-SP80	Bronze Gate, Globe, Angle and Check Valves

Number	Title
Industry Standard Specifications, Codes, and Guidelines	
NACE-STD	National Association of Corrosion Engineers Cathodic Protection
-RP-02-75	Application of Organic Coating to External Surface of Steel Pipe for Underground Service
NASA	National Aeronautics and Space Administration
-NSS/GO-1740.9	NASA Safety Standard for Lifting Devices and Equipment
NEMA	National Electrical Manufacturers Association
-MG1	Motors and Generators
NFPA	National Fire Protection Association
-13	Installation of Sprinkler Systems
-13A	Inspection, Testing and Maintenance of Sprinkler Systems
-54	National Fuel Gas Code
-70	National Electrical Code
-72E	Automatic Fire Detectors
-78	Lightning Protection Code
-80	Fire Doors and Windows
-85B	Standard for Prevention of Furnace Explosions in Natural Gas-Fired Multiple Burner Boiler
-90A	Installation of Air Conditioning and Ventilating Systems
-99	Standards for Health Care Facilities
NIOSH	Technical Report: Guide to Industrial Respiratory Protection
NIST	National Institute of Standards and Technology
NSS	National Safety Standards
O	
SBC	Standard Building Code
SMACNA	Sheet Metal and Air-Conditioning Contractors National Association
-	High Pressure Duct Construction Standards
-	Low Pressure Duct Construction Standards
-	Guidelines for Seismic Restraints of Mechanical Systems
-	Round and Oval Duct Construction Standards
-	Architectural Sheet Metal
SSPC	Steel Structures Painting Council
-SP-2	Surface Preparation, Hand Tool Cleaning
-SP-3	Surface Preparation, Power Tool Cleaning
-SP-10	Surface Preparation, Near-White Blast Cleaning
UBC	Uniform Building Code
UFAS	Uniform Federal Accessibility Standards
UFC	Uniform Fire Code
UL	Underwriter's Laboratories

Number	Title
Industry Standard Specifications, Codes, and Guidelines	
-96	Lightning Protection Systems
-181	Factory Made Air Ducts and Connectors
-467	Grounding and Bonding of Equipment
-555	Leakage Rated Dampers for Use In Smoke Control Systems
-586	High Efficiency Particulate, Air Filter Units
-900	Test Performance of Air Filter Units
-1072	Medium Voltage Power Cables
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code
USGSA	United States General Services Administration
-	Certification Test for Air Flow Measuring Stations

5.4 Site Specific Reference Documents

Number	Title
SITE SPECIFIC REFERENCE DOCUMENTS	
RFP-YM 193	Request for Proposal No. YM 193 for LIGO Facility Design and Construction Management Support
ashington DOT	Standard Specifications for Road and Bridge Construction
ashington DOT	Standard Plans for Road and Bridge Construction
Louisiana DOTC	Standard Specifications for Road and Bridge Construction
Louisiana DOTC	Standard Plans for Road and Bridge Construction
941208-01	LIGO Vacuum Equipment Request for Proposal No. MH 178
941219-01	Hanford -- Land Use Permit
941219-02	Hanford -- Memorandum of Understanding
941219-03	Hanford -- Environmental Assessment
941219-04	Hanford -- Finding of No Significant Impact
941219-05	Hanford -- Report of Geotechnical Survey/Letters of Clarification
941219-06	Hanford -- Staking Survey
941219-07	Hanford -- Topographical Survey/Including Back-up Data and Seven Diskettes
941219-08	Hanford -- Specification and Contract Documents for Rough-Grading
941219-09	Hanford -- Drawings for the Rough-Grading
941219-10	Hanford -- Ground Water-Temporary Permit
941220-02	Beamtube Module Specification
941223-01	Information for Potential Contractors -- Facilities Contract
941228-01	Livingston -- Act of Cash Sale (Draft)
941228-02	Livingston -- Lease Agreement (Draft)
941228-03	Livingston -- Environmental Assessment (Draft Final, One Copy)

Number	Title
SITE SPECIFIC REFERENCE DOCUMENTS	
	Finding of No Significant Impact (Appendix B)
941228-04	Livingston -- Section 404 Permit
941228-07	Livingston -- Staking Survey
941228-08	Livingston -- Drainage Plan with Hydrologic and Hydraulic Report
941228-10	Livingston -- Conceptual Designs for Pipeline Crossings of the LIGO Embankment
941228-11	Beam Tube Enclosure Statement of Work and Beam Tube Support Details
950104-01	Utility Conduit Design Calculations and Drawing
950112-03	Proposed Layout of LIGO Office and Shop Areas
950112-04	Livingston -- Lease Agreement
950112-05	Livingston -- Geotechnical Investigation, Final Report
950113-01	Hanford -- LIGO Rough Grading (with 12 diskettes)
950201-01	Hanford -- Water Well Drilling Log

6. Design Criteria and Interface Requirements

6.1 General Facility Requirements

- A. Units of measurement are in English units.
- B. "Master Spec" will be used as the Guideline Construction Specification.

6.1.1 Fabrication and Construction Tolerances

The A-E will provide, in the drawings and specifications, all tolerances for fabrication, construction, and installation.

6.1.1.1 Structural Steel

Minimum tolerances for structural steel construction will be per the AISC "Code of Standard Practice for Steel Buildings and Bridges".

6.1.1.2 Concrete

Minimum tolerances for concrete construction and materials will be per ACI 117, "Standard Specification for Tolerances for Concrete Structures and Materials".

6.1.1.3 Installed Equipment

Tolerances for equipment interfaces specified by the A-E will not exceed the manufacturer's tolerance requirements.

6.1.2 Service Life

6.1.2.1 Facility Design Life

Facility design will be for a 30 year service life.

6.1.2.2 Systems and Equipment Design Life

Systems and equipment design will be for a 20 year service life.

6.1.3 Construction Category

The LIGO project will be categorized as permanent, noncombustible construction, Type II, 1 hour fire rated in accordance with the UBC and SBC.

6.1.4 Occupancy

Each LIGO project site will be designed for a maximum shift population with 40 personnel at the Hanford, Washington, and for 30 at the Livingston, Louisiana. The breakdown of anticipated personnel and their classification is as follows:

Staff	Quantity
Technician and/or Operators	10
Technician Specialists	3
Engineers	3
Site Administration	2
Scientific Staff	3
Visiting Scientists	6
Interns and/or Visitors	9

6.1.5 Design

Design of the facility will comply with the Industry Standards and Specifications referenced therein and good design principles. The Facility will be designed for ease of maintenance and operability.

6.1.6 Safety

Construction of the facilities will comply with OSHA-Title 29.

6.1.7 Security

Security of the facilities will comply with _____. The major security effort will be to design for minimum potential intrusion particularly along the beam tube enclosures.

6.1.7.1 Perimeter Penetrations

Vents, ducts, louvered openings, pipes, conduit, etc., that penetrate the facility's perimeter (i.e. exterior walls and roof) will receive the following special treatment.

- A. Air handling ducts that penetrate the perimeter (roof or exterior walls) will contain non-conductive sections positioned within 6 inches of the inner (secure) side of the wall or roof.
- B. Wireways, raceways, and conduit will contain non-conductive sections within 6 inches of the inner (secure) side of a wall and roof.
- C. Metal pipe penetrations will be treated with lead wrap foil, 1/8 inch thick for a distance of 12 inches, on the inner (secure) side of a wall or roof (Section 6.5.2.3).

6.1.8 Material Selection

6.1.8.1 Flame Spread

All materials will be noncombustible or have a flame spread rating of 25 or less in accordance with ASTM E84.

6.1.8.2 Cleanliness/Contamination

- A. Design will use non-corrosive and/or corrosion resistant material as required.
- B. Exclude use of fraying or other material that could contribute to contamination in the Clean Room.
- C. Preclude ledges that may trap dirt and minimize oil leakage from mechanisms and mechanical equipment.
- D. Consideration will be given to out-gassing and particle generation of the materials.
- E. All materials will be compatible with the cleanliness requirements of the room's classification (e.g., Class 1,000, Class 50,000, etc.).

6.1.8.3 Material Compatibility

As a design goal, all material selections should be made such that Non Volatile Residue (NVR) deposition, in the LVEA, does not exceed 0.5 mg/square foot/month in accordance with MIL-STD-1246.

6.2 Civil

6.2.1 General Civil Requirements

This section addresses the requirements for site preparation and earthwork, hydrology and drainage, roads and paving, parking, utilities, wastewater treatment and other site improvements. The A-E shall determine whether existing drainage, soil conditions, and subsurface conditions are adequate; or, how best to ensure adequacy for the least cost. Area contours shall be provided by Caltech.

Careful attention will be paid in development of the site to the special needs of LIGO and of the individual site characteristics. Establishing and maintaining alignment are important considerations at both sites.

Caltech shall provide soil conditions and allowable design parameters through examination of existing records and performance of geotechnical investigations.

6.2.2 Coordinate Control

6.2.2.1 Hanford

The intersection of the two beam tube arms is located at latitude $46^{\circ} 27' 18.5''$ N and longitude $119^{\circ} 24' 27.1''$ W. The northeast arm is at a bearing of $N36.8^{\circ}W$ and the southwest arm is at a bearing of $S53.2^{\circ}W$. For further coordinate and site boundary information see Figure 6.2-1

6.2.2.2 Livingston

The intersection of the two beam tube arms is located at latitude $30^{\circ} 33' 46.0''$ N and longitude $90^{\circ} 46' 27.3''$ W. The northeast arm is at a bearing of $N18^{\circ}W$ and the southwest arm is at a bearing of $S72^{\circ}W$. For further coordinate and site boundary information see Figure 6.2-2

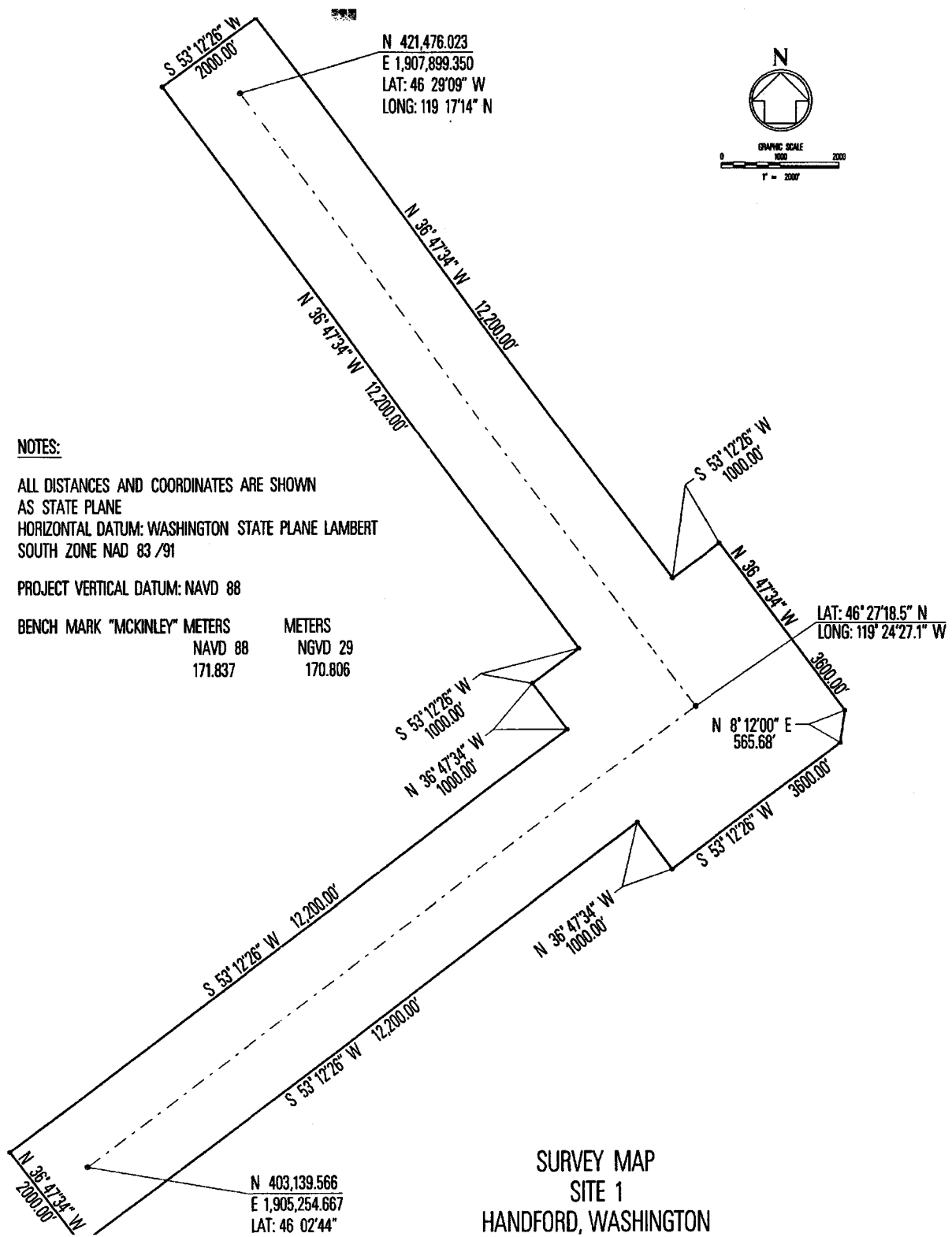
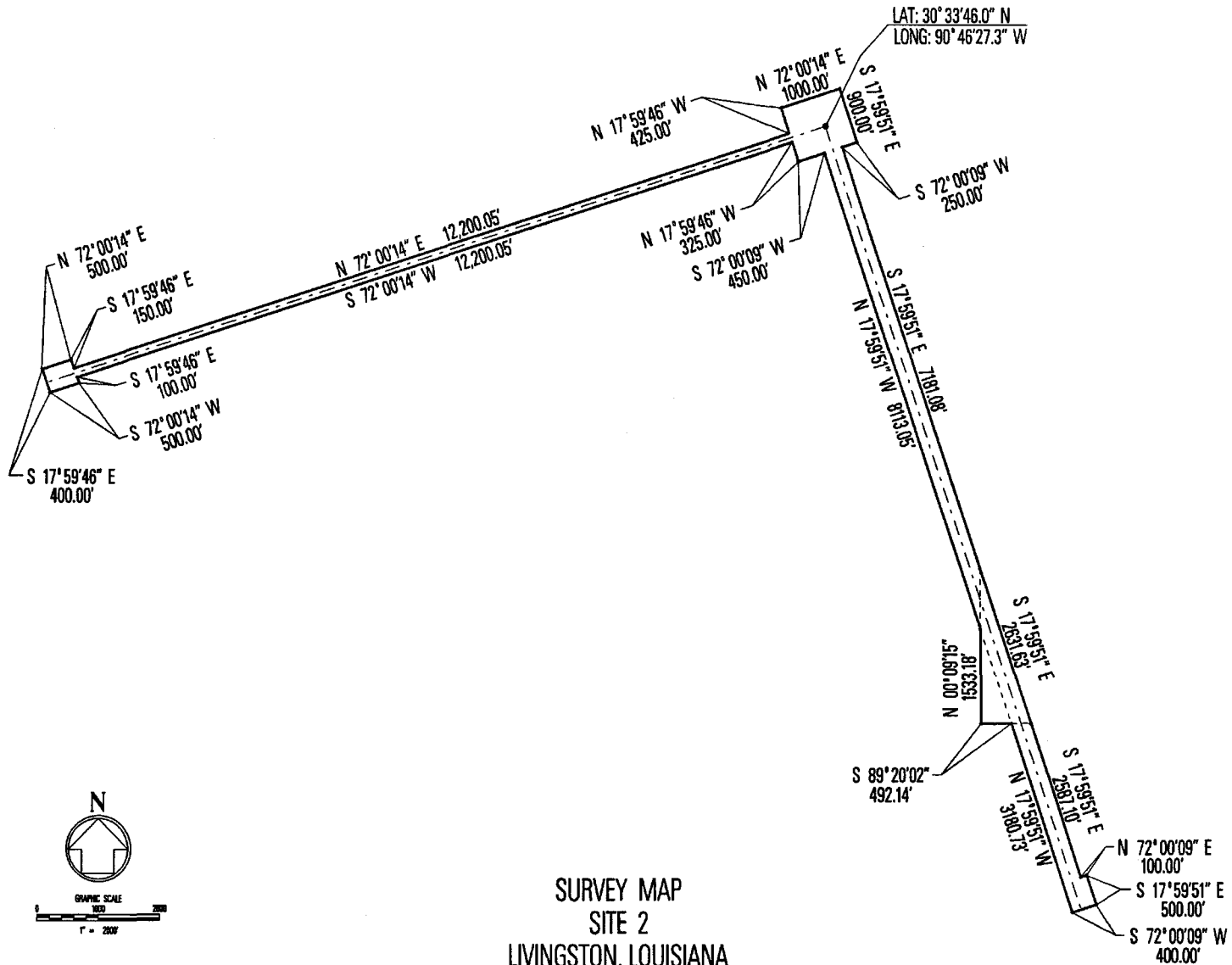


Figure 6.2-1



SURVEY MAP
 SITE 2
 LIVINGSTON, LOUISIANA

Figure 6.2-2

6.2.3 Site Preparation and Earthwork

Roads and graded areas shall be laid out to minimize environmental damage. Natural drainage patterns shall be maintained to the maximum extent possible. All site areas will be graded away from buildings.

Earthwork slopes and grading shall be in accordance with the recommendations of the geotechnical reports and the following:

- A. Cut slopes shall be 1:2
- B. Fill slopes shall be 2:1
- C. Graded area pads shall be sloped 2% minimum for drainage
- D. At Livingston a minimum freeboard of 3 feet shall be used above the 100 year storm level
- E. The beam tube arm embankments shall be flat graded from the corner station to the end stations (i.e., tangential from the corner station to a radial from the Earth's center). This requirement may be modified by $\pm 0.314159 \times 10^{-3}$ radians, and the embankment of the two beam tube arms must create a planar surface at each individual site.
- F. The beam tube embankment shall be designed to minimize settlement

6.2.4 Roads, Paving and Parking

The project roads shall consist of a main access road to the facilities and the beam tube enclosure(s) service roads. Paved service roads along each arm provide access to the beam tube at 250 meter intervals as well as access to the end and mid stations.

Parking for permanent staff and visitors will be provided. A frost penetration depth of 24 inches shall be considered for the Hanford design.

6.2.4.1 Roads

The road geometrics and cross-sectional design shall be in accordance with the following:

- A. Roads shall be designed to positively drain with a cross slope of 2%.
- B. Roads shall have a shoulder width of 4 feet with a cross slope of 4%.
- C. Road side slopes shall generally be 2:1.

- D. Road corner radii shall be no less than 35 feet.
- E. Road grades shall not exceed 6%.

6.2.4.2 Paving

Paving design for the facility roads and parking areas shall be in accordance with the following:

- A. The pavements shall be designed to provide two-lane all weather access.
- B. All access roads shall be flexible pavement.
- C. Axle loading for roads shall be AASHTO H-20.
- D. CBR value for pavement design shall be [per geotechnical reports]

6.2.4.3 Parking

Parking spaces shall be provided and designed in accordance with the following:

- A. Parking for the main facilities (corner station) shall be for:

- 1) {TBD} employees (including maintenance vehicles)
- 2) {TBD} visitors
- 3) {TBD} handicap
- 4) {TBD} buses

- B. Parking for the end station shall be for:

- 1) {TBD} employees (including maintenance vehicles)
- 2) {TBD} visitors
- 3) {TBD} handicap

- C. Parking for the mid station shall be for:

- 1) {TBD} employees (including maintenance vehicles)
- 2) {TBD} visitors
- 3) {TBD} handicap

6.2.5 Site Drainage

All drainage systems shall be designed to properly drain all surface water that can cause damage to the facilities, property, and adjoining land. A storm frequency of 100 years will be used for all drainage structures.

6.2.5.1 Ditches

Sheet drainage to open ditches will be used to the maximum extent possible. Ditches shall be no steeper than 3:1 to facilitate mowing where required.

6.2.5.2 Pipes

Pipes or closed conduits will be used for drainage when open ditches interfere with the intended use of the area. Pipes shall be reinforced concrete.

6.2.5.3 Culverts

Culverts shall be provided under roads or the beam tube embankment and whenever the natural drainage pattern is interrupted. Culverts shall comply with the following requirements:

- A. Minimum diameter = 24 inches
- B. Minimum gradient = 1%
- C. Alignment shall be in the direction of storm flow and as nearly perpendicular to roads, embankments or obstructions as possible

6.2.6 Utilities

The domestic water supply and the sanitary sewer system for the corner station shall be designed for a total work force of {TBD} on a {TBD} shift basis. Water and sanitary sewer requirements for the mid-stations and end stations are {TBD}. Firewater will be designed for {TBD} gpm per {TBD} hours demand in accordance with NFPA and local requirements. Fire protection for the mid-stations and end stations are {TBD}. Other utilities are discussed within the design criteria for the responsible discipline.

6.2.6.1 Potable Water

- A. Potable water shall be provided from a well(s) located {TBD} for Livingston and an existing well located near the end station of the southern arm for Hanford.

- B. Potable water shall be pumped to a storage tank to accommodate facility requirements and to minimize well pump start/stops.
- C. Potable water shall be distributed from the tank to all facilities via an underground system.
- D. The potable water distribution system shall be in accordance with the following:
 - 1) Design velocity shall be 5 fps, with a maximum of 10 fps
 - 2) Minimum earth cover of 3 feet
 - 3) Backflow preventers will be provided at connections with the possibility of contamination.
 - 4) Water supply shall be designed for the combined peak flow requirement

6.2.6.2 Firewater

- A. Firewater shall be provided from a well(s) located {TBD} for Livingston and an existing well located near the end station of the southern arm for Hanford.
- B. Firewater shall be pumped to a storage tank to accommodate facility requirements and to minimize well pump start/stops and to provide the required fire water reserve necessary per code.
- C. A standby diesel engine driven firewater pump shall be provided in case a complete power outage occurs
- D. Fire hydrants will be strategically placed around the facility. At branch lines to fire hydrants gate valves shall be provided. Hydrant spacing shall be 300 feet maximum.
- E. Post indicator valves will be provided at each building sprinkler connection.
- F. Valving for fractional isolation of the fire water system will be provided if necessary.

6.2.6.3 Sanitary Sewer

Sanitary sewer pipelines will be designed in accordance with the following:

- A. The minimum line size will be 6 inches diameter
- B. Design velocity will be a minimum of 2 fps flowing at half depth or 3 fps when cleaning is difficult

- C. Sewers will have straight runs between manholes (if manholes are needed)
- D. Cleanouts will be used for changes in direction of minor sewer laterals and building connections

6.2.7 Wastewater Treatment Facilities

Federal, State, and local codes regarding collection, treatment and discharge of sanitary wastes will be met. Sewage collected from the LIGO facilities at Hanford will be treated by a septic tank system with disposal through a leach field system. Sewage collected from the LIGO facilities at Livingston will be processed through a package tertiary wastewater treatment plant with discharge to natural waterways.

6.2.8 Miscellaneous Sitework

6.2.8.1 Solid Waste Disposal

Solid waste (trash) shall be collected by a locally contracted solid waste disposal firm from a facility location {TBD}

6.2.8.2 Security Fencing

Security fencing shall be limited to the area around the corner station and will consist of a 6 foot chain link fence with 3 strands of barbed wire at the top. Gated access from the main access road shall be provided. No guard station is required.

6.2.8.3 Pipeline Crossings

There are two oil company pipelines crossing the Livingston site. These pipelines will be protected or rerouted in a method {TBD}.

6.3 Structural

6.3.1 General Structural Requirements

6.3.1.1 Steel Design and Construction

Steel structures and components will be designed and constructed in accordance with the AISC Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design, and the AISC Code of Standard Practice for Steel Buildings and Bridges. All structural welding will be in accordance with AWS D1.1, A2.4 and A3.0.

6.3.1.2 Concrete Design and Construction

Concrete structures and components will be designed and constructed in accordance with ACI 318.

6.3.1.3 Concrete Reinforcing Steel

Steel reinforcement will conform to the requirements of ASTM A615, Grade 60. Detailing, fabrication and placement will be in accordance with CRSI-1.

6.3.1.4 Masonry Design and Construction

Masonry structures and components will be designed and constructed in accordance with ACI 530.

6.3.1.5 Inspection Requirements

Inspection requirements, along with acceptance criteria, for steel and concrete structures and components will be clearly specified by the A-E in the drawings and specifications.

6.3.2 Loading Conditions

Structural systems and components will meet or exceed the requirements of both ASCE 7-88 (formerly ANSI A58.1) and the UBC code for Hanford or Standard Building Code (SBCCI) for Livingston.

6.3.2.1 Minimum Floor Live Load

The minimum floor live load will be as follows:

- A. 250 psf for storage and receiving areas

- B. 100 psf for control room, shops and LVEA areas
- C. 50 psf for office area

6.3.2.2 Seismic Load

- A. Seismic loads will be applied and the structure analyzed using one of the methods described in the UBC for the Hanford site. Seismic loads will be applied and the structure analyzed using the equivalent static method per SBCCI for the Livingston site.
- B. At the Hanford site, the structure is located in seismic zone 2B per UBC. At the Livingston site, the seismic classification is Hazard exposure group I, performance category A, per SBCCI.

6.3.2.3 Wind Loads

Wind loads, for the Hanford site, will be determined in accordance with UBC using a design wind speed of 70 MPH, exposure C and importance factor I. Wind loads, for the Livingston site will be determined in accordance with SBCCI using a design wind speed of 100 MPH, exposure C and importance factor I.

6.3.2.4 Forklift Loads

A 25,000 pound capacity forklift will operate anywhere within the boundaries of the facility.

6.3.2.5 Interior Vehicular Surface Loads

The following interior areas will be designed per AASHTO H-20.

- Shipping and Receiving
- LVEA
- Cleaning Area
- Inspection Area

6.3.2.6 Volcanic Ash Loads

The Hanford site structures will be designed for a volcanic ash load of TBD psf.

6.3.2.7 Load Combinations

Load combinations will be in accordance with the UBC for the Hanford site and SBCCI for the Livingston site.

6.3.2.8 Serviceability Requirements

- A. Deflections due to live load, wind or seismic will be limited as follows:
- 1) Maximum allowable live load deflection will be $L/240$, except for elements supporting plaster ceilings or wall in which case the maximum will be $L/360$.
 - 2) Seismic lateral drift will meet or exceed the requirements 0.005 times the story height.
- B. Vibration Transmission: The structure will be designed so as to minimize transmission of vibration to the LVEA foundation. See Section 6.7 for additional information on Vibration Isolation.

6.3.2.9 Beam Tube Foundation and Enclosure Requirements

- A. Initial beam tube slab "straight line" variance of finish floor will be limited to $\pm 1/2$ inch for the entire length of all beam tube arms (Distance = 4 km).
- B. Initial slab "straight line" variance of finish floor will be limited to $\pm 1/4$ inch in 10 feet.
- C. The foundation at the beam support must be constructed to a tolerance of $\pm 1/2$ inch between the successive supports (about 65 ft).
- D. The long term differential settlement is limited to ± 0.8 inches with reference to the laser line.
- E. Any excessive differential settlement above the 0.8 inches may have to be taken care of by adjustments in the beam tube supports.
- F. End flanges or valves where vacuum pressure can exist on one side only, will require support from the foundation to react to the entire force due to the differential pressure.

- G. Beam Tube Enclosure will be capable of stopping penetration of a stray bullet. The parameters to be used are as follows.

Item	Property
Caliber:	308
Weight:	180 Grains
Velocity at Impact:	2900 Feet Per Second
Energy at Impact:	2800 Foot-Pounds
Material:	Lead Core, Fully Jacketed with Copper

6.4 Architectural

The LIGO Project is comprised of a facility for the Corner Station containing a cleanroom for the Laser Vacuum Equipment Area (LVEA), with support areas for maintenance and administrative functions. Other facilities are the beam tube enclosures, Mid- and End-Stations, and utility buildings for conditioned air, power and water/waste treatment. These structures are to be located at both Hanford, Washington and Livingston, Louisiana. The only difference is the Mid-station at Livingston will be a mid-point Pump Station that does not house special vacuum equipment chambers.

6.4.1 Life Safety

The LIGO Project will be designed in accordance with UBC, SBC, and NFPA 101. These codes and standards are followed to provide emergency exits and exit access ways as applicable.

6.4.2 Finishes

- A. All architectural finishes are compatible with internal and external environments described in Section 6.5.2.1
- B. All paints and coatings will conform to the States of Washington and Louisiana local Air Pollution Control District requirements respectively.

6.4.2.1 Floor Finishes

- A. Interior concrete floor surfaces for LVEA have seamless flooring which meet the clean environment.
- B. Other exposed interior concrete floor surfaces have a smooth steel trowelled finish, with a surface hardener.
- C. Control room and computer spaces have access flooring.
- D. Offices, lobby and receptionist areas have carpet.
- E. All other interior spaces have resilient floor tile. Toilet facilities have ceramic tile.
- F. Exterior concrete floor surfaces have a broom finish. Special concrete finishes are designated for the main entry to the Corner Station.
- G. Joint filler and sealer materials are resistant to the effects of the induced environment as required.

6.4.2.2 Walls

- A. Exterior walls will be proven architectural materials and will be insulated, weather resistant materials providing an air- and water-tight, maintenance free enclosure.
- B. Exterior walls are TBD.
- C. Precast concrete arches are used for the beam tube enclosures.
- D. Interior walls for the "clean areas" are smooth, non-shedding, and compatible with Class 1,000 and 50,000 clean environments respectively.
- E. Interior walls for administrative and maintenance areas are standard gypsum board and metal stud construction with paint finish.
- F. Interior walls for toilet areas are Water Resistant (WR) gypsum board and metal stud construction with ceramic tile.

6.4.2.3 Ceiling Finishes

- A. Ceilings will be suspended type or acoustical tile in general areas such as offices, lobby and computer rooms.
- B. Suspended hard surfaced ceilings in the clean areas will be in areas compatible with Class 1,000 or 50,000 clean environments respectively. Materials will be selected as required to meet acoustic requirements as described in Section 6.8, Acoustics.
- C. Other areas, such as toilet facilities, locker rooms, and janitors rooms, will have suspended hard surfaced ceilings.
- D. Exposed ceiling/roof structure will be used in other areas such as Shipping/Receiving, shop areas, and utility spaces.
- E. WR gypsum board will not be used for ceiling applications.

6.4.2.4 Painting -- General

- A. All exposed and untreated materials requiring protection are field painted.
- B. Surfaces are finished, cleaned and dry prior to receiving painting.
- C. Material is primed with one coat 0.5 mils dry film thickness of paint primer.

- D. Material receives one intermediate coat and one finish coat of paint. The intermediate coat is a different color than the finish coat. Each coat is a minimum of 3 mils dry film thickness.
- E. Surfaces not to be painted:
 - 1) Concrete floors
 - 2) Glass
 - 3) Masonry, unless specified
 - 4) Precast concrete, unless specified
 - 5) Factory finished items
 - 6) Items specified in construction documents as surfaces not to be painted
- F. All colors will be in accordance with the color palette as established by the architect and the Caltech Technical Representative. The finish coat of all painted interior clean room surfaces is white.

6.4.2.5 Painting (Metals), Shop and Field

6.4.2.5.1 General

All exposed ferrous and nonferrous metal (including copper and galvanized surfaces) to be installed are shop or field painted.

6.4.2.5.2 Surface Preparation

- A. Ferrous metal surfaces preparation will be in accordance with Steel Structures Painting Council (SSPC) specifications.
- B. Blast cleaning is in accordance with SSPC-SP-10. In areas where sand blasting is not allowed, surfaces are prepared in accordance with SSPC-SP-2 and/or SSPC-SP-3.

6.4.2.5.3 Prime Coating

- A. Ferrous metals are painted with one coat, 3 mils dry film thickness
- B. Nonferrous metals are prime coated with 0.5 mils dry film thickness of primer.

6.4.2.5.4 Finish Coating

All ferrous and nonferrous metals receive one intermediate coat and one finish coat. The intermediate coat is a different color than the finish coat. Each coat is to be a minimum of 3 mils dry film thickness.

6.4.2.5.5 Surfaces not to be painted

- A. Air terminals (Lightning Protection System)
- B. Ladder rungs
- C. Chain rails and hoist points
- D. Bridge crane wheel/wire rope/rail interfacing surfaces
- E. Lightning connectors/down cable isolation blocks
- F. Stainless steel, brass and bronze
- G. Top surface of aluminum floor plates
- H. Aluminum handrails
- I. Handrail post sockets
- J. Wear surfaces of hinges or mechanisms
- K. Winch cable drums
- L. Factory finished items

6.4.2.5.6 Colors

All colors will be in accordance with the color palette as established by the architect and the Caltech Technical Representative. The finish coat of all painted interior clean room surfaces is white.

6.4.2.6 Caulk and Sealant

Caulk/tape/sealant used in each type of cleanroom is compatible with the classification of the cleanroom environment.

6.4.3 Clean Room Interior Design

To ensure that the LVEA meets clean environment requirements of Section 6.5.2.1.2 the interior surfaces of these areas will be designed to the following criteria:

- A. Minimize horizontal ledges and surfaces
- B. Fully enclose all structural shapes
- C. Line all necessary pockets and recesses with cleanable shapes
- D. Cove all inside corners
- E. Provide seams that will not retain soil or dust
- F. Provide smooth, non-flaking and washable surfaces and finishes
- G. Provide closed chases for pipes and conduits where possible
- H. Provide access for cleaning all surfaces
- I. Provide flush/surface mounted lighting fixtures

6.4.4 Doors - General

- A. The clean room door opening mechanisms design will minimize the amount of contaminants generated by their operation.
- B. All doors in the clean room perimeter walls will be equipped with weather-strips and seals in order to minimize air leakage/loss from clean environments and contamination.

6.4.4.1 Equipment Doors

All equipment doors will be sized to accommodate the passage of a piece of support equipment measuring TBD long x TBD wide x TBD high.

6.4.4.2 Large Access Doors

- A. All large access doors will be power actuated (with provisions for manual override), insulated and will provide a finished clear opening of TBD wide and TBD wide. See Section 6.6.11 for door control requirements.
- B. All large access doors will be installed per NFPA 80.

6.4.4.3 Personnel Doors

- A. Personnel doors will be 3'-0" wide x 7'-0" high insulated hollow metal doors.
- B. All doors will be 1-3/4" thick (minimum).
- C. UBC, SBC, and NFPA requirements will be applied when fire rated doors are required.
- D. Door hardware will comply with Industry Codes and Standards.
- E. Specialized door hardware will include automated entry control and intrusion detection devices, door mounted combination locks, deadbolts and padlocks, exit hardware, electric strikes/latches, electric power transfers, heavy duty door closers, lock cylinders, sound or weather seals, automatic door bottoms, hinges with non-removable pins, and associated equipment.

6.4.4.4 Thresholds

Thresholds will be flush with the floor.

6.4.5 Roofs and Gutters

Roofing design for structures will meet the requirements of UBC and SBC. Roof penetrations will be eliminated if at all possible. Rain Gutters and/or roof drains with overflow drains will capture all roof runoff and direct it to an appropriate storm drain system.

6.4.6 Energy Conservation

"U" values for roofs and exterior walls will be determined in accordance with the governing state codes for energy conservation, or with ASHRAE design guidelines.

6.4.7 Specific Area Requirements

6.4.7.1 Laser and Vacuum Equipment Area

- A. The Laser and Vacuum Equipment Area (LVEA) is approximately 65,000 square feet for the Hanford, Washington site and 40,000 square feet for the Livingston, Louisiana site.
- B. The LVEA ceilings has heights to accommodate overhead crane systems to accommodate movement of equipment components for repair, maintenance, and replacement.

- C. LVEA floors have a durable surface to withstand occasional highlift traffic, a noise reduction capability, reduce vibration, and a seamless covering to maintain the cleanroom classification.
- D. LVEA walls have a durable, cleanable surface of an inorganic, and a non-gassing finish to maintain the cleanroom classification.

6.4.7.2 Cleanroom

- A. The Cleanroom is approximately 500 square feet (minimum), and is directly accessible to the LVEA via the Inspection and Cleaning Area and an airlock/anteroom.
- B. The room has a class 1000 cleanroom rating.
- C. An access door with a minimum size of TBD wide x TBD high is provided to allow direct access from the Inspection and Cleaning Area to the Clean Room.
- D. The flooring is seamless sheet vinyl or liquid epoxy coating. Walls are gypsum board with an epoxy coating.
- E. The ceiling height is TBD (maximum). The ceiling material is suspended gypsum board with an epoxy coating.
- F. Provision will be made for installation of laminar-flow workstations within these spaces which will maintain local workspaces at Federal Standard 209D Class 100 or better conditions.

6.4.7.3 Experimental Equipment Area

- A. The Experimental Equipment Area is approximately 1600 square feet and adjacent to the Testing Area.
- B. Materials and finishes are durable and cleanable. Floors are resilient flooring. Walls and ceilings are painted gypsum board.

6.4.7.4 Testing Area

- A. The Testing Area (TA) is approximately 1200 square feet and accessible to the Inspection and Cleaning Area.
- B. Materials and finishes are durable and cleanable. Floors are resilient flooring. Walls and ceilings are painted gypsum board.

6.4.7.5 Inspection and Cleaning Area

- A. Inspection and Cleaning Area is approximately 1000 square feet in size and immediately adjacent to the LVEA.
- B. The ceiling height is TBD (maximum).
- C. An overhead equipment door is provided to allow direct access to the LVEA from the Inspection and Cleaning Area with access to the Cleanroom via an anteroom/airlock.
- D. An additional overhead equipment door is provided from outside the LIGO facilities for access and deliveries via the loading dock.
- E. Materials and finishes are durable and cleanable. Concrete floors are sealed. Walls and ceilings are painted gypsum board.

6.4.7.6 Computer Room

- A. The Computer Room and Computer Users Room is adjacent and accessible to the Control Room and Experimental Testing Area.
- B. Floors are raised access floor system.
- C. Walls are painted gypsum board. Ceiling height is 10'-0" (maximum) and suspended acoustical tile system.
- D. A single door is provided to allow access for personnel and equipment.

6.4.7.7 Control Room

- A. The Control Room is adjacent and accessible to the LVEA via the Clothing Change Room.
- B. Floors will be raised access floor system.
- C. Walls are painted gypsum board. Ceiling height is 8'-0" (maximum) and suspended acoustical tile system.
- D. A single door is provided to allow access for personnel and equipment.

6.4.7.8 Clothing Change Room

- A. The Clothing Change Room accommodates 10 personnel, is approximately 150 square feet (minimum), and is directly accessible to the LVEA via the Control Room.

- B. The room is equipped with 40 lockable 12" wide x 24" deep x 36" cubicles and portable benches.
- C. A single door is provided to allow access for personnel.
- D. The flooring is sheet vinyl.
- E. The ceiling height is 8'-0" (maximum) and is painted gypsum board.

6.4.7.9 Beam Tube Enclosures

- A. Enclosures is arched, concrete structures approximately 6 inches thick and with a radius of approximately TBD.
- B. Service access to enclosure is every 250 meters (850 ft).
- C. Emergency access to enclosure is every 90 meters (300 ft).
- D. Enclosures is ventilated to control excess humidity and is provided with utility power.
- E. Floors are sealed concrete sloped to floor drain.
- F. Structure is water tight, vermin and insect proof, and resistant to bullets (see section 6.3.2.9).

6.4.7.10 Mid-Station Facilities

Facility areas follow height and material criteria for like spaces of the Corner Station.

6.4.7.11 End-Station Facilities

Facility areas follow height and material criteria for like spaces of the Corner Station.

6.5 Mechanical

6.5.1 General Mechanical Requirements

6.5.1.1 Mechanical System and Component Identification

Mechanical system and component identification comply with the requirements stated in ANSI A13.1 for lettering, colors, band widths, marker locations, and viewing angles.

6.5.1.2 Wind Loads

All exposed mechanical equipment and plumbing piping systems are to be designed to withstand wind loads as specified in ASCE 7-88.

- A. For non-critical systems, the Importance Factor equals unity.
- B. For critical systems, the Importance Factor equals 1.11.

6.5.1.3 Corrosion Control

Corrosion control measures include cathodic protection systems, copper-finned coils and tubes, as well as, the use of protective coatings.

- A. The use of protective coatings will be in accordance with NACE-RP-02-75.
- B. Protection will be provided against corrosion caused by galvanic action due to physical contact of dissimilar metals.

6.5.1.4 Factory Paint

- A. Unless otherwise specified, all ferrous and nonferrous metal to be installed inside the facility will have surfaces prepared in accordance with SSPC-SP-10 and shop primed with two-part, organic zinc rich epoxy for ferrous metals, or organic zinc rich chromate primer for non ferrous metals.
- B. Field painting will be in accordance with Section 6.4.2.4.

6.5.1.5 Vibration Control

- A. All rotating pieces of equipment will be statically and dynamically balanced as a complete assembly.
- B. Maximum amplitude of any rotating piece of equipment will be 2 mils peak-to-peak, at all steady state operating speeds.

6.5.1.6 Motors

All motors will be high-efficiency type, non-overloading in accordance with Section 6.6.2.

6.5.1.7 Safety Requirements

Provide the following safety requirements:

- A. Belts, pulleys, chains, gears, protruding set screws, keys and other rotating parts will be fully enclosed or properly guarded in accordance with OSHA 29 CFR 1910.219.
- B. High temperature equipment and piping so located as to endanger personnel or create a fire hazard will be properly guarded or covered with insulation.
- C. Where required for safe operation and maintenance of equipment, provide such items as catwalks, platforms, ladders, and guard rails.

6.5.1.8 Redundancy

- A. Provide redundancy by including a standby unit for all critical areas which are served by only one air handling system.
- B. For air handler units (AHUs) supplying air to Clean Rooms (i.e, LVEA, Clean Room, etc.), there will be one standby for each area. Redundant critical components are an acceptable alternative to providing complete redundant AHUs.
- C. For chillers, boilers, pumps and air compressors, there will be at least one standby unit.
- D. All redundant equipment will be provided with automatic start capability, with manual override.

6.5.2 Heating, Ventilating, and Air Conditioning Systems

The Heating, Ventilation and Air Conditioning (HVAC) systems will be designed for optimum energy conservation and operational cost. Centralized automatic control and system surveillance will be provided by the facility control and data acquisition system. In response to the strict vibration and acoustic requirements imposed by the interferometers, the HVAC system will incorporate the following features:

- A. The location of machinery, chiller plants, high-velocity exhausts, etc. will be chosen to limit atmospheric transmission of noise.

- B. Equipment will be provided with vibration isolators and flexible connectors for ducts, electrical conduits, and piping to avoid structural transmission of vibrations and acoustic noise.
- C. Diffusers, grills, fans, heating and ventilating units, and other equipment will be carefully selected to meet or exceed the noise criteria for the serviced area
- D. Excessive velocity and turbulence in ducts and piping will be avoided everywhere.
- E. To limit noise transmission through the ventilating ducts, intra-duct acoustic attenuators will be installed, where necessary.

6.5.2.1 Design Conditions

6.5.2.1.1 Climatic Design Criteria

Environment	Hanford	Livingston
Nearest Town	Richland, WA	Baton Rouge, LA
Latitude	47 N	30 N
Longitude	119 W	91 W
Elevation	392 ft above sea level	65 ft above sea level
Summer Outdoor Design Temp	96 °F _{db} , 68 °F _{wb}	93 °F _{db} , 80 °F _{wb}
Daily Temp Range	30 °F	19 °F
Winter Outdoor Design Temp	5 °F _{db}	25 °F _{db}
Clearness Number, Summer	1.05	0.9
Clearness Number, Winter	0.95	0.9
Design Wind Velocity, Summer	3.6 mph	7.5 mph
Design Wind Velocity, Winter	15 mph	15 mph

6.5.2.1.2 Inside Design Conditions

Space	Design temperature	Air flow rate
Vacuum equipment operating (HI- and Lo-bay areas)	72 ± 2 °F, 40 ±5% RH 0.1" wg above outside ambient	15 Ach/Hr (clean air class 50,000)
Laminar flow work benches	72 ±2 °F, 40 ±5% RH 0.05" wg above adjacent area	45 Ach/Hr (clean air class 100)
Operation area clean rooms	72 ±2 °F, 40 ±5% RH 0.05" wg above adjacent area	30 Ach/Hr (clean air class 1,000)
Interferometer optic work and electronic shop areas.	72 ±2 °F, 40 ±5% RH 0.05" wg above adjacent area	30 Ach/Hr (clean air class 1,000)
Inspection Area, Cleaning Room, and Smock Room	72 ± 3 °F, 40 ±5% RH 0.01" wg above adjacent area	2 cfm / sf
Central Control Room, Racks, and Data Archives Room	72 ± 3 °F, 40 ±10% RH,	1.5 cfm / sf
Receiving and Shipping Area	75 ±5 °F	1 cfm / sf
Offices	72 ±3 °F	1.5 cfm / sf
Main Lobby	72 ±3 °F	1.5 cfm / sf
Conference Room	72 ±3 °F	1.5 cfm / sf
Electrical Equipment Room	80 to 60 °F	As required
Utility and Mechanical Rooms	80 to 60 °F	As required
Boiler Room	10° F above ambient summer max; 55 °F min winter	As required
Break Room	75 ±5 °F	1 cfm / sf
Toilets	72 °F	2 cfm / sf exhaust
Beam Tube Enclosure	No special temperature required, maintain 30 to 50% RH and 0.01" wg above ambient	Minimal

6.5.2.2 Insulation Systems

All thermal insulation systems materials will be noncombustible as defined by ANSI/NFPA 220.

6.5.2.3 Penetrations

- A. Perimeter (exterior walls and roof) penetrations will be protected in accordance with Section 6.1.7.1.

- B. Effective sound stopping, vapor sealing, and adequate operating clearances will be provided to prevent structure contact where ducts and pipe penetrate walls, floors, or ceilings into occupied spaces.

6.5.2.4 HVAC Air Systems

HVAC air systems design will comply with the Uniform Mechanical Code (UMC), applicable SMACNA publications, including but not limited to, HVAC Duct Construction Standards - Metal and Flexible; Rectangular Industrial Duct Construction Standards; Round Industrial Duct Construction Standards; Accepted Industry Practice for Industrial Duct Construction; HVAC Systems Duct Design; and HVAC Air Duct Leakage Test Manual.

6.5.2.4.1 Air Handling Units

- A. Air handling units will have automatic restart capability in the event of site power failure.
- B. Air handling units will not be mounted on the roof, and other roof penetrations will be avoided.
- C. Refrigerant coils will not be used in clean room system, since CFC is a contaminant itself.

6.5.2.4.2 Ductwork

Ductwork (See Section 6.1.8.3) will conform to the following requirements:

- A. Duct system will be capable of withstanding static pressure variation +10%, and without pulsating.
- B. Waveguide devices will be provided at duct penetrations through all EMI shielded walls, ceilings, and partitions.
- C. Fire dampers will be provided at duct penetrations through fire rated walls, ceilings, and partitions.

6.5.2.4.3 Air Filters

- A. All filters will be fire resistant type, nonallergenic, and nontoxic, with no detectable odors.
- B. Dry filter gaskets will be closed-cell foamed neoprene or urethane elastomer of sufficient hardness to compress not more than 40 percent of original thickness when the filter is in position.

C. High-Efficiency Particulate Air (HEPA) Filter:

- 1) HEPA filters will be capable of withstanding minimum 90% relative humidity determined dynamically between 70 and 100 degrees.
- 2) HEPA filters will bear numbered Underwriter's Laboratories label certifying the filter is UL 586 classified.
- 3) HEPA filters will provide, as a minimum, a 99.97% overall efficiency on 0.3 micron particles.
- 4) Dioctylphalate (DOP) tested HEPA filters are not acceptable. DOP mist is a contaminant.
- 5) HEPA filters will be located down stream of supply air fan system.

6.5.2.4.4 Humidifiers

- A. Humidifiers may be electric, evaporative, or clean steam.
- B. Electric and evaporative humidifiers will utilize reverse osmosis water as water source.
- C. Electrode/jug type humidifiers are not acceptable.

6.5.2.5 HVAC Hydronic Systems

6.5.2.5.1 Chillers

- A. In general, each chiller will be a complete, factory tested, water chilling package consisting of compressors, capacity control system, water cooler, refrigerant condenser, starters, disconnect, and steel base.
- B. Chillers will be rated in accordance with ARI 540.
- C. Chillers will comply with the ASME Code, Section VIII.
- D. Control panels will be provided integral to the chiller unit.
- E. Control panels will have the capability to interface with the HVAC Control and Monitoring System (See Section 6.5.6.2).
- F. The chillers will operate smoothly within the 15% to 100% capacity range without surge or vibration.

- G. The chillers will have an automatic restart capability in the event of site power failure.

6.5.2.5.1.1 Chlorofluorocarbon Limitation

- A. The contractor will supply the most cost-effective chiller type using an acceptable alternate refrigerant (No CFCs) as allowed by the Clean Air Act.
- B. Comply with the refrigeration equipment room requirements specified in ASHRAE Standard 15-1992, and safety classification of refrigerants based on ASHRAE Standard 34-1992.
- C. No refrigerant will be present inside the clean air flow stream, by design, single point failure, or accident.

6.5.2.5.1.2 Condensers and Cooling Towers

- A. Air or water cooled condensers are acceptable.
- B. Water cooled condensers will reject heat through induced draft type cooling towers.
- C. Towers will be of noncombustible construction and conform with NFPA Standard 220 requirements.
- D. Design and construction of steel members will conform to AISC S326.

6.5.2.5.2 Boilers

- A. Provide packaged, steel water tube boilers for producing hot water including all necessary Local Code trim and appurtenances.
 - 1) Boilers will have State approval, UL listed and be designed, constructed, and labeled for the design working pressure in accordance with the latest edition of the ASME Power Boiler Code.
 - 2) Boilers will be factory assembled, factory tested, self-contained, easily transported, ready for automatic operation except for connection of water, fuel, electrical and vent service.
 - 3) Diesel fuel is not an acceptable energy source.
 - 4) Provisions will be made for collection and storage of boiler blowdown water.

- 5) Boilers will have an automatic restart capability in the event of site power failure.
 - 6) Boilers will be of the multiple quick recovery type producing hot water.
- B. Locate boilers separately from the rest of the HVAC equipment as required by the UBC.

6.5.2.5.3 Water Treatment

Water treatment system, equipment to be based on site water tests, will be furnished to provide a source of treated water for boiler, humidifier, condenser and chilled water makeup.

6.5.2.5.4 Pumps

- A. Pump will be capable of accommodating static pressure variations of plus or minus 10%.
- B. Pumps will have an automatic restart capability in the event of site power failure.

6.5.2.5.5 Chilled Water, Condenser Water, and Heating Water Piping

- A. Piping will be as a minimum Schedule 40 black steel conforming to ASTM/ANSI A53.
 - 1) Fittings will conform to:
 - a) ANSI B16.3, minimum Class 150; and,
 - b) ANSI B16.9; ANSI B16.5; or, ASME Boiler and Pressure Code, Section VIII.
 - 2) Fittings 2" and smaller may be threaded.
- B. Piping 4" and smaller will be copper ASTM/ANSI B88, hard drawn, Type K (underground and exposed use) and Type L (aboveground and concealed use).
- C. Copper fittings will comply with ANSI/ASME B16.29; joints, ANSI/ASTM B32, solder grade 95TA.
- D. Route piping parallel with building lines with branch runs extended from the top of the mains and with pipe transitions in the eccentric to avoid cavitation and facilitate venting of air.
- E. Provide vents at high points and drains at low points.

- F. Provide unions or flanges at equipment connections to facilitate removal and maintenance.

6.5.2.5.6 Valves

- A. Valves will be angle, ball, check, gate, globe, and automatic or manual balancing types.
 - 1) Valves will have rising stems and open when turned counterclockwise.
 - 2) Provide valves to permit isolation of branch piping and each equipment item to permit balancing of the system.
 - 3) All valves 2" or smaller will be ball valves.
- B. As a minimum, manual and control valves will conform to the following:
 - 1) Bronze Gate, Check: MSS SP80.
 - 2) Cast Iron Gate: MSS SP70.
 - 3) Butterfly: MSS SP67, ASTM A126, and ANSI B16.1.
 - 4) Ball: FED-STD WW-V-35 or MSS SP72, Class 150, flanged.
 - 5) Cast Iron Check: MIL-V-18436, Class 125.
 - 6) Globe and Angle: MSS SP80.
 - 7) Standard Check: MSS SP80 or ASTM A126.
 - 8) Non-Slam Check: ASTM A278.
- C. Control valve actuators will conform to the following:
 - 1) Will be electric, pneumatic (large actuators only) or electronic for Direct Digital Control.
 - 2) Will have a feature that allows conversion to accept new controller output signal without having to replace the motor actuator.
 - 3) Valve actuators will be industrial grade, spring return, or non-spring return type.
- D. Balance valve will be a circuit setter or an automatic balancing device such as variable orifice, precisely calibrated, and able to preset, balance and meter the flow and will have the following:

- 1) Positive cutoff.
- 2) Flow memory.
- 3) Readout ports.
- 4) Vent connection.

6.5.2.5.7 Pipe Supporting Elements

With the exception that C-clamps will not be used, supporting elements will comply with the requirements of ANSI/ASME B31.1, ANSI/MSS SP-58, and MSS SP-69.

6.5.3 Industrial Grade Piping Systems

6.5.3.1 Clean Dry Air

- A. Provide clean dry and oil free compressed air at a nominal pressure of 125 psig.
- B. Air will be filtered and regulated to achieve the cleanliness requirements of the room supplied.
- C. Clean dry air capacity will be 150 SCFM at 100 psig air pressure at point of delivery.

6.5.3.1.1 Air Compressor

- A. Use a central compressed air system to serve multiple points of use.
- B. Provide centrifugal or rotary helical screw type, air-cooled.
- C. Air compressor will be an oil free type, 125 psig operating pressure, complete with air receiver, ASME code rated and stamped for 300 lb test, air filter and aftercooler.
- D. Comply with standards of Compressed Air and Gas Institute (CAGI).
- E. Air compressors will have an automatic restart capability in the event of site power failure.
- F. The air receiver will be able to supply the air requirements for a minimum of 4 hours in the event of power failure (control/instrument air only).

6.5.3.1.2 Air Dryer

The air dryer will be a refrigeration type capable of maintaining air at 35°F to 39°F pressure dew point.

6.5.3.1.3 Compressed Air Piping

- A. Compressed air piping will be copper ASTM B88, hard drawn fittings to comply with ANSI/ASME B16.29; joints, solder grade 95TA.
 - 1) Piping will be oxyclean per CGA 4.1 or cleaned in accordance with ASTM B280 as required by application.
 - 2) Cleaned tubing will be capped and pressurized with nitrogen, in accordance with CGA 4.1.
- B. For piping above grade use type "L" copper, and for below grade use type "K".

6.5.3.2 Gas Piping

Provide gas piping for natural gas fired boiler.

6.5.4 Plumbing Systems

6.5.4.1 Potable Water

6.5.4.1.1 Flushing Water

- A. Within the LVEA provide a potable water connection (standard 3/4 inch hose bib) to supply 5 gpm (min) at 50 psig (max).
- B. Provide a potable water connection (standard 3/4 inch hose bib) in a wash down area outside the LVEA adjacent to the exterior door to supply 5 gpm (min) at 50 psig (max).

6.5.4.1.2 Backflow Prevention Devices

- A. Provide backflow prevention device to prevent contamination of potable water supply system.
- B. Backflow preventer will be a reduced pressure principle backflow type in accordance with UPC, Section 1003 general requirements; ASSE 1013-1971.

6.5.4.2 Drains and Vents

6.5.4.2.1 Floor Drains

- A. Provide floor drain with trap for the wash down areas and for all eyewash/eyeshowers, specified in Section 6.5.4.1.1, as required by local directives.
- B. Provide automatic trap priming device.
- C. All required water drains will be routed to an appropriate waste collection system, as required by local directives.

6.5.4.2.2 Plumbing Materials

Select materials based on water quality that conform the minimum requirement in UPC.

6.5.4.2.3 Eyewash and Showers Equipment

- A. Eyewash/showers will be a combination type single head emergency shower and eyewash.
 - 1) Number of installations will be based upon the number of people and the size of the hazardous area.
 - 2) Use materials that will resist corrosion.
 - 3) Provide emergency sign, hand and foot control.
- B. Design supply line using a minimum water pressure of 30 psi.
- C. Eyewash/showers will comply with ANSI Z358.1.
- D. Eyewash/showers required will be placed outside of the clean room, adjacent to emergency exits.

6.5.5 Fire Suppression and Detection Systems

The design, installation and testing of the fire sprinkler systems will be in accordance with NFPA 13, and NFPA 13A.

All fire alarm, detection, and fire suppression systems will be interconnected, and monitored by central fire reporting systems in accordance with NFPA Standard. Fire protection systems will be suitable for use with computers and other electronics.

6.5.6 Facility Monitoring and Control Systems

The status of all fans, pumps, hoists, vents and other facility equipment which can produce vibration, acoustic noise or electrical interference is sensed, reported to the Facility Monitoring and Control Systems and updated periodically. This allows operators to track possible instrumentation interference problems to specific pieces of facility equipment, even if that equipment is activated autonomously or intermittently. See Section 6.10 for a matrix showing Facility Monitoring and Control Nodes.

6.5.6.1 Control System Design

- A. The sequence of operation will be presented clearly and concisely.
- B. Each mode of operation will specify operating ranges, valve and damper positions (fail open or closed) for the following functions:
 - 1) Heating
 - 2) Humidification
 - 3) Dehumidification
 - 4) Cooling
 - 5) Economizer

6.5.6.2 HVAC Control and Monitoring System

6.5.6.2.1 Control Devices

- A. Provide all sensor/transmitter control devices as a completely assembled unit, manufactured and assembled by one supplier, with calibration traceable to National Institute of Standards and Technology (NIST, formally NBS) standards.
- B. Sensor/transmitter assemblies will be factory assembled, calibrated, and shipped as a single entity.
- C. Assembly will be compatible with the HVAC control and monitoring system.
 - 1) All control devices will be selected for minimum accuracy of 1% except temperature and dew point sensors will have a minimum accuracy of 0.5% over the control range.
 - 2) Components will be specified with regards to functional attributes and not solely on manufacturer model numbers.

- 3) Controls will be housed in enclosures that are ventilated and will be mounted indoors in an air conditioned environment.

6.5.6.2.2 Operator Interfaces

Operator interface will be provided for status monitoring from central control room which provide on line operator interaction, supervision, coordination and control.

6.5.6.2.3 Control Points

- A. The system will control all significant points of the central chiller and boiler plant and the air handling systems.
- B. The system will interface with the environmental control and monitoring system.
- C. The following monitor and control point for the HVAC system will include but not limited to the following:
 - 1) Temperature (local and remote).
 - 2) Humidity (local and remote).
 - 3) Flowrate (Air and Hydronic Systems).
 - 4) Pressure.
 - 5) Remote start/stop status, and run time.
 - 6) Filter differential pressure indication.
 - 7) Dewpoint monitoring.
 - 8) System on-off operation (local and remote).
 - 9) Changeover control.
 - 10) Vapor detection status.
 - 11) All necessary boiler, chiller, pump, condenser and damper controls (status, run time, and operation selection).

6.5.6.3 Particulate Monitoring System

- A. Provide a particulate monitoring system for the Class 1000 Clean Rooms, using optical counter technology of either a manifold, multiplexing type or an individual sample point type. Locate particulate monitoring points near the return air grilles

and supply air terminals in accordance with IES recommended practices and procedures, FED-STD-209D and ASTM F50 and F328.

- 1) Maximum time for collection of the 20 sample point particles shall be less than 5 minutes.
 - 2) Acceptable sample flowrates shall be within the range of 0.1 cfm to 1 cfm with statistical analysis and standard deviation features based on FED-STD-209D.
- B. Provide output for communication with a remote monitoring workstation in the Control Room.
- 1) Workstation shall have color monitor and graphics capability for real-time monitoring and trend analysis capabilities.
 - 2) Provide long term data storage in 15 minute time intervals for a 24 hour time period, full reporting features including alarms and conditions, and statistical analysis features based on FED-STD-209.
 - 3) Provide multilevel password protection for system access.

6.5.7 Cranes

6.5.7.1 General Crane Requirements

- A. Electric overhead traveling bridge cranes are required in LVEA of the Corner Station, the Vacuum Equipment Area of the End Stations at both sites, and the Mid Station at the Hanford Site. These cranes will be underhung, single girder type.
- B. Cranes will comply with the requirements of CMAA #74, ASME HST M4, ANSI B30.2, B30.10, NEC Article 610, and AWS D14.1.
- C. Cranes will operate in non-hazardous environment.
- D. Cranes will have a 20 year design life based on CMAA #74 class "C" service.
- E. The cranes will be suitable for operation in a Class 50,000 clean room environment as defined in FED-STD-209.
- F. The cranes hoist will be electric wire rope type and will conform to the requirements of ASME HST M4.
- G. Operation of the cranes will be monitored by the Facility Monitoring and Control Systems (see Section 6.5.6).

6.5.7.2 Crane Capacity

The LVEA cranes will have a rated capacity of 5 tons for all low-bay cranes and 10 tons for the high-bay cranes.

6.5.7.3 Lift Height at the Corner Station

The hook height for the low-bay crane will be _____ feet, and for the high-bay crane will be _____ feet.

6.5.7.4 Lift Height at the Mid and End Stations

The hook height will be _____ feet.

6.5.7.5 Crane Electrification

Crane electrification will be by the means of _____.

6.5.7.6 Hoist Reeving and Wire Rope System

- A. The hoists will have a double reeving and will have a true vertical lift capability.
- B. The ropes for the hoists will consist of one right and left regular lay, be of pre-formed stainless steel and will be sized for a minimum of 5:1 safety factor.

6.5.7.7 Hoist Brakes

The hoists will be equipped with double braking system. Emergency holding brake will be applied automatically when power to the brakes are removed.

6.5.7.8 Crane Drives

- A. Hoist:
 - 1) Drives will have a variable speed ranging from ____ to ____ fpm with creep mode capability.
 - 2) The maximum drive acceleration/deceleration rate will be 0.1 g
- B. Trolley and Bridge:
 - 1) Drives will have a variable speed ranging from ____ to ____ fpm with creep mode capability.

- 2) The maximum drive acceleration and deceleration rate will be 0.1 g

6.5.7.9 Crane Control

The cranes will be operated by a _____ control system. An emergency stop button will be incorporated in the control system which will set all brakes and stop all crane motion when depressed.

6.5.7.10 Drip Pans

The cranes will be provided with stainless steel drip pans installed under motors, gear boxes, hoist drums, and other components where leakage of grease, oil, or other contaminants could occur. Drip pans will be designed to permit easy removal of collected lubricant.

6.5.7.11 Manual Load Lowering Capability

The crane hoist will have an emergency load lowering capability such that in the event of a power failure or any other equipment failure, the crane operator has the capability of manually lowering any load up to the rated capacity from any hook height.

6.5.7.12 Special Requirements

- A. A solid state electronic horn will be provided on the crane. Any bridge and trolley motion will be accompanied by a continuous series of alternating tones.
- B. An overload sensor and alarm light will be provided to halt the hoisting operation and alarm the operator when the load exceeds the preset maximum.

6.6 Electrical

6.6.1 Area Classification

There are no areas in this facility that are defined by the NFPA as "Hazardous Locations". The contents and processes used in this facility do not necessitate using equipment or installation practices suitable for hazardous locations.

6.6.2 Electrical System Description

The electrical system receives power from the local servicing utility, most likely an Rural Electrification Administration (REA) affiliate, depending on the site location. The power will be brought onto the site in underground conduit. The power is transformed by a 2000 kVA Double-ended substation from the utility voltage to 4,160 V for distribution to the major power using centers of the facility and to the mid- and end-stations. The power is transformed from 4,160 V to 480/277 V, 3-phase and 208/120 V, 3-phase near the points of use. The nominal frequency of the power shall be 60 Hz. Grounding and circuit neutrals will be in accordance with accepted industry practice and NEC.

6.6.3 Electrical Equipment

- A. Electrical equipment shall be designed in accordance with ANSI C2 and NFPA 70 (NEC).
- B. Motors: Fractional and integral horsepower motors shall conform to NEC code letter G or better, NEMA MG1, UL, and NEC, continuous duty induction type. Motors shall meet or exceed nominal full-load efficiency of 91%.
- C. Electrical equipment that contains electronic devices or sub-assemblies shall be able to meet the electro-magnetic interference (EMI) emission limits expressed in FCC Rule 15 subpart J, Class A.
- D. Transient suppression devices or equipment that provides transient suppression shall comply with UL 1449 requirements.
- E. Electrical equipment and circuits shall be located in the facility so as to minimize influences upon the LIGO experiment and data handling equipment.

6.6.4 Receptacles

Receptacles fed from appropriate voltage and current circuits will be installed throughout the facility. The locations, voltage, current and plug type will be coordinated with the users. Receptacles in office areas shall be distributed with a minimum of one duplex

receptacle on each wall, with spacing not to exceed 12 feet on center, unless otherwise indicated.

6.6.5 Lighting

6.6.5.1 Illumination

Illumination levels shall be as specified in this paragraph for each occupancy type. Lighting instruments and fixtures shall be distributed and arranged to reduce glare and specular reflection.

Occupancy	Illumination Level [fc]
General Offices	50
Workrooms	50
Corridors	25
Storage Areas	10
Laser and Vacuum Equipment Area	5 to 25 ¹
Clean Room	100
Equipment Rooms	25

- A. Illumination levels shall be measured at 30 inches above finish floor (AFF) unless otherwise specified.
- B. Interior lighting color shall have a Color Rendering Index (CRI) of 75 or greater as rated per the Illuminating Engineers Society of North America (IESNA) Handbook.
- C. Lamp selection shall be based on current industry standards for power efficiency ratings.
- D. Low Pressure Sodium (LPS) lighting shall not be used. High Pressure Sodium (HPS) with a CRI greater than 60 will be used outdoors.
- E. Areas that are furnished with lamps exhibiting non-instant-on operating characteristics shall include auxiliary lamps that provide reduced illumination levels during the period that the main lighting achieves full brightness.
- F. Lamps may be energized with direct-current when EMI and experimental equipment considerations dictate.

¹ Normal Operations at 5 foot-candles. Provisions for general illumination lighting at 25 fc

6.6.5.2 Controls

- A. Lighting controls for office and corridor type spaces shall be local, unless otherwise specified, and adjustable to provide approximately 1/3, 2/3, and full illumination levels.
- B. Lighting controls for the LVEA and other high-cubic volume areas shall be centrally located.
- C. Lighting controls for closets and for spaces under 100 square feet shall provide one level of lighting only.

6.6.5.3 Emergency Lighting

Self-contained (battery pack) emergency lighting in accordance with OSHA Standards and NEC Article 700 shall be used in all occupied areas.

6.6.6 Crane

The LVEA crane electrical power, controls, and readout systems shall meet the requirements of the clean environment. The LVEA is classified as non-hazardous. The power electronics in the crane drives shall not introduce EMI into the LVEA.

6.6.7 Electrical Power Characteristics

From the RFP, the estimated power requirements for the scientific equipment is outlined in the following preliminary load summary:

Vacuum pumps	Peak ² (kW)	Average ³ (kW)
Beam tube rough pumping	200 ⁴	-
Chamber rough pumping	33 ³	1
Ion pumps (during first year of operation)	6	-
Ion pump (site fully operational)	-	1
Electronic equipment	200	100
Shop and service equipment	60	28
Chamber bakeout heaters	80 ³	-
Lasers (including cooling)	320 ³	160

² Short term peak (e.g., motor starting) transients excluded.

³ Average power consumption after startup of operations.

⁴ Will not operate simultaneously.

Medium voltage commercial power is available from the local utility power company at each site. Power distribution will be from the main substation transformer, located near the corner station. Required voltages include 480 volt three phase power, 208 volt three phase power, and normal 120V circuits. The distribution system must provide a grounding and lightning protection scheme which is suitable for sensitive scientific equipment.

Electrical power shall be provided by two distinct systems. Large motor loads such as air-handling equipment and vacuum roughing pumps and lighting will be fed from the facilities power network. Sensitive electronic equipment will be fed from a technical power network. The two networks differ by the amount of electrical isolation and transient voltage suppression that is provided.

6.6.7.1 Facility Power

Facility electrical power characteristics shall be in accordance with ANSI C84.1-1982 and ANSI/IEEE Std. 141-1986, and shall meet the following minimum requirements:

Parameter	Range
120 volts nominal	108 to 132V ($\pm 10\%$)
480 volts nominal	432 to 528V ($\pm 10\%$)
Harmonics Content	5% Total Harmonic Distortion (THD)
Frequency	60 Hz ± 1 Hz

Transients shall not exceed +10% of the specified voltage for a duration exceeding 200 microseconds.

6.6.7.2 Technical Power

- A. Technical electrical power will be derived from the Facility Power network.
- B. Technical power shall be available to furnish sensitive electronic equipment directly related to the LIGO experiment.
- C. Technical power feeders shall be isolated from facility power feeders by using ultra-isolator transformers and transient voltage surge suppressors at the power distribution panels.
- D. Technical power shall not be common with any other facility loads that are 480V or lower.

- E. The power quality of the technical power system shall meet the performance levels indicated in FIBS PUB 94 and as required for successful LIGO experiment results.

Parameter	Range
120 volts nominal	110 to 125V (+4%, -8%)
480 volts nominal	440 to 500V (+4%, -8%)
Harmonics Content	5% THD for nonlinear loads
Frequency	60 Hz \pm 1 Hz

6.6.7.3 UPS Power

Uninterruptible power system (UPS) power will be derived from the Technical Power network. Power conditioning equipment, including motor generators, UPS, and direct current (dc) power supplies will be provided when commercial power quality and operational requirements are in conflict. Power conditioning equipment that is provided shall be operated successfully in accordance with PHIBS PUB 94. The UPS power equipment shall meet the following requirements:

Parameter	Range
RF Emissions	In accordance with FCC Part 15, Subpart J, Class A
Common Mode NRR	-120 dB up to 100khz
Harmonics Content	5% THD
Transverse Mode NRR	-60dB up to 100khz
Surge Protection	IEEE 587/ANSI C62,41 Category B
Acoustical Noise	Less than 50 dBA at one meter distance
Total Harmonic Distortion	5% for nonlinear loads
Voltage Regulation	\pm 2%.
Frequency	60 Hz \pm 1 Hz

6.6.7.4 Backup Power

There is no requirement to provide backup power for this facility. Safe shutdown power for the vacuum control equipment and the data processing equipment shall be provided by the Corner Building UPS.

6.6.7.5 Power Distribution System

- A. 25% spare capacity shall be provided throughout the Facility and Technical Power distribution systems.
- B. Power distribution panels and equipment will be clearly identified.
- C. Power distribution diagrams and circuit schedules of the distribution panels will be provided.

6.6.7.5.1 Electric Outlet Reference Designator

A unique identification designator shall be printed and affixed near each electrical outlet to identify the circuit breaker panel, circuit breaker designator and voltage.

6.6.7.5.2 Circuit Breaker Reference Designator

A unique identification designator shall be printed and affixed near each circuit breaker correlating with the outlet reference designator.

6.6.8 Materials

- A. Copper conductors, buses and transformer winding shall be used throughout the electrical system.
- B. All air plenum and cable chase cables shall be shielded, and rated as air plenum type.
- C. Plastic insulated and jacketed cables shall be in conformance with NFPA and IEEE smoke evolution and flame spread requirements.
- D. Polymeric materials shall not introduce Volatile Organic Compounds (VOC) or out-gassing products in the enclosed spaces.

6.6.9 Grounding

The LIGO shall have a power equipment grounding system in accordance with NFPA-70 (NEC)

The LIGO grounding system shall consist of the following subsystems described and detailed in NFPA-70 (NEC) and FIPS-94 and IEEE Std-1100 (Emerald Book).

- A. Facility Ground Subsystem
- B. Technical Ground Subsystem
- C. Signal Reference Subsystem (Single-Point Ground)
- D. Lightning Protection Subsystem
- E. Equipment Fault Protection Subsystem

6.6.9.1 Resistance to Earth

- A. The dc resistance to earth from any point of the Grounding System shall be 10 ohms or less.
- B. Where 10 ohms cannot be obtained with basic electrode configuration due to high soil resistivity, rock formations, or other terrain features, alternate methods for reducing the resistance to earth shall be considered.

6.6.9.2 Facility Ground

The primary power shall be grounded only at the neutral of the transformer in accordance with the NEC.

6.6.9.3 Technical Ground

- A. Technical power shall be isolated from primary utility power by the utility transformer and utilization voltage isolation transformers.
- B. The dc resistance between the primary and technical power shall be at least 1 megohm.
- C. The various technical power subsystems shall have dc isolation resistance of 1 megohm.
- D. All single phase and three phase transformers shall have grounded secondary points in accordance with the NEC.

6.6.9.4 Signal Reference Ground

The signal reference shall be designed as a single-point grounding connection point for instruments that are sensitive to ground loops.

6.6.9.5 Lightning Protection Grounding

The LIGO lightning protection subsystem shall be designed in accordance with appropriate provisions of NFPA 78, UL 96 and UL 467.

6.6.9.6 Grounding Plates

Technical ground plates shall be provided at the Experiment Power and Utility Outlets located in the LVEA. The connections between the ground plates and the grounding cabling shall be bolted, to allow for isolation and testing. These ground plates shall be

isolated from the facility ground with appropriate hardware. The dc resistance between these grounding plates and other grounds shall be 1 megohm or more.

6.6.9.6.1 Physical Description

The grounding plates shall be 3/8" (thick) x 2" (wide) x 6" (long) minimum copper bar with six nontapped 3/8" holes.

6.6.9.6.2 General Installation

The grounding plates shall be located 12 inch (min.) above the floor and 4 inch from mounting surfaces on insulating supports or other appropriate devices.

6.6.9.6.3 Installation Locations

Clean Room Area technical and facility grounding plates shall be provided at workbench locations and spaced at 12 ft intervals (minimum) around the perimeter of the Clean Room.

6.6.9.7 Crane Hook Grounding

See Section 6.5.7, Cranes for crane hook grounding requirements.

6.6.9.8 Bonding

All metal-to-metal bonds within the LIGO shall be in accordance with NEC requirements for electrical equipment and devices and ASHRAE recommendations for ductwork and air handling equipment.

6.6.10 Fire Detection System

A Fire Detection System in accordance with NEC Article 760 and NFPA 72E in concert with the Fire Suppression System defined in Section 6.5.5 shall be provided.

6.6.11 Doors and Controls

- A. Power shall be provided as required for the motorized doors.
- B. Controls on both sides of the wall containing the door adjacent to the door opening, with provisions for manual override shall be provided.
- C. The ability to lock out the operation of either door control shall be provided.

- D. The ability to switch control from either door control station to the other shall be provided.

6.6.12 Clean Room Area

6.6.12.1 Facility Power

Spacing between receptacles shall not exceed 12 feet on center throughout the Clean Room perimeter, see Section 6.6.4.

6.6.12.2 Technical Power

Technical power characteristics and isolation shall be per Section 6.6.7.2.

6.6.12.3 Lighting

6.6.12.3.1 Illumination

The average illumination levels shall be 100 foot candles (fc) (see Section 6.6.5.1).

6.6.12.3.2 Lighting Controls

Lighting controls for the Clean Room shall be local, unless otherwise specified, and adjustable to provide approximately 1/3, 2/3 and full illumination levels.

6.6.12.4 Particulate Monitoring System

- A. Required power and wiring for the Particulate Monitoring System as defined in Section 6.5.6.3 shall be provided.
- B. Readout displays shall be located the 1000 Class Clean Room Area.

6.6.13 Computer and Control Room

- A. Power in the computer and control room shall be filtered technical power.
- B. Lighting shall be filtered, and electromagnetically shielded.
- C. Technical ground plates shall be provided.

6.6.14 Beam Tube Enclosures

- A. The beam tube enclosures shall be provided with basic lighting and convenience power.
- B. Provisions shall be made to feed power to future Ion Getter pumps at 250 meter intervals along the beam tube length.
- C. Beam tube bake-out power requirements shall be satisfied with portable generators brought in for the occasion.

6.6.15 Electromagnetic Compatibility (EMC)

LIGO interferometer equipment is sensitive to stray electric magnetic field interference, particularly at radio frequencies. Attention will be paid to stray magnetic loops from power distribution, and EMI from lighting and power supplies and equipment power controllers.

The LIGO shall be designed to achieve EMC within the facility in accordance with MIL-STD-461D Section 6.3.

6.6.16 Communication Systems

The facility will be served by an internal communications system which may involve a combination of telephones and intercoms. The system will provide sufficient capability to serve the needs of widely dispersed teams working on coordinated installation and integration tasks.

The equipment will consist of:

- A. Administrative telephones with on and off site access,
- B. Public address and area warning system, and
- C. Tie-ins to a Local Area Network that serves the entire facility.

6.6.16.1 Conduits

- A. All communication conduits shall be routed separately from other conduits.
- B. Materials shall be steel, of Intermediate Metallic Conduit Grade or heavier.
- C. Conduit and raceway networks shall be bonded and electrically continuous in accordance with NEC.

6.6.16.2 Distribution Boxes

All distribution boxes shall be supplied with a non-conductive, fire-resistant back mounting panel.

6.6.16.3 Fiber Optic Network

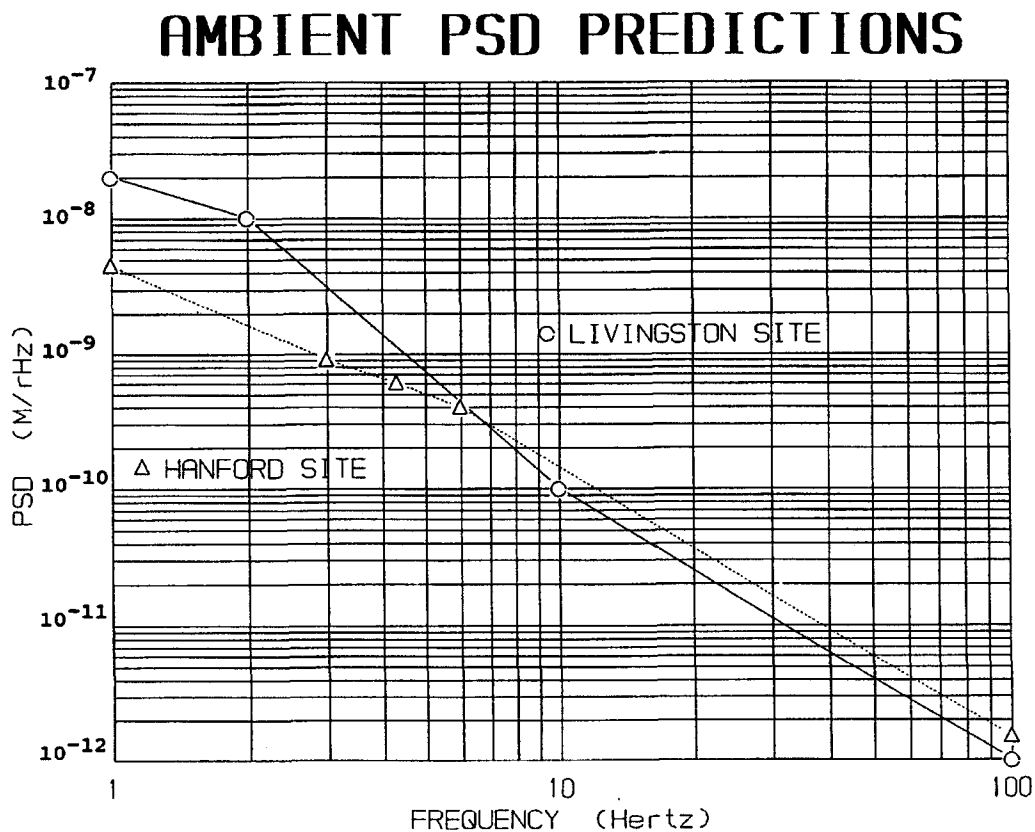
A broad-band fiber optic network shall be provided to carry signals of the Facility Monitoring and Control System. This fiber optic network shall be isolated from the experiment fiber optic backbone.

6.7 Vibration Isolation

The facility vibration criteria for the Hanford, Washington Site and the Livingston, Louisiana site are defined in Appendix C, Special Building Needs, of the LIGO Facility Strawman Design. The LIGO goal is to design and build a completed, operating facility which does not increase the Power Spectral Density (PSD) plots by more than a factor of two above the natural background. This is to be accomplished over the frequency range from one Hertz to one hundred Hertz, measured at the foundation for the Laser Vacuum Equipment Areas (LVEA). Exceptions may be allowed over narrow frequency bands, above ten Hertz, to permit specific operating equipment to exceed these levels caused by a spike in the foundation PSD at the operating frequency of specific equipment.

The preliminary estimate of the ambient PSD spectra for the Hanford, Washington site and for the Livingston, Louisiana site is shown below. The design basis, measured ambient PSD levels, will be defined by site investigations that will be completed during the winter of 1995 at Hanford and during the summer of 1995 at Livingston.

This graph shows estimates of the displacement power spectral density in m/\sqrt{Hz} of the ground at the Livingston and Hanford sites before construction.



6.8 Acoustics

6.8.1 Laser Facility and End Stations Background Noise

The acoustic background level due to mechanical equipment associated with the building facility will be limited to a PNC 40 (Preferred Noise Criterion) between 8 Hz to 10 KHz. The main concern is minimizing acoustic noise in the frequency band below 100 Hz.

6.8.2 Offices Space Background Noise

Office space background noise environment will be designed to a PNC 35.

6.8.3 Reverberation Times

In order to control reverberant noise the LVEA and Vacuum Equipment Areas at the Mid and End Stations will be designed to a reverberation time of no more than 1.5 ± 0.2 seconds at the mid-frequencies (500 and 1,000 Hz.).

6.8.4 Exterior to Interior Noise Control

Exterior to interior noise reduction will be approximately 50 dB at the mid-frequencies. This will be designed for a source located on the ground outside the facility such as a heavy truck as measured in the LVEA and Vacuum Equipment Areas at the Mid and End Stations.

The design will not include control of rain-generated noise.

6.9 Utility Matrix

Notes:		Electrical							Comm.					Mechanical										Handling								
208 = 3 Phase, 208/120 V 480 = 3 Phase, 480/277 V 120 = 1 Phase, 120 V		Facility Power	Technical Power	UPS	Lightning Grnd	Instrumentation Grnd	Technical Grnd	Facility Grnd.	Ethernet/LAN	Telephone	Wireless Transceiver	Public Address System	Close Circuit Video	Potable Water	Sewage	Drainage	Clean/Dry Instrument Air	Shop Air	Nitrogen Gas	Dionized Water	Natural Gas	Exhaust Vents	Clean Air Supply	Positive Pressure	Hose Bibs for Washdown	House Cleaning Vacuum Ports	Fire Extinguishers	Fire Suppression	Fire Detection and Alarm	Particulate Monitoring	Bridge Cranes	Mono Rails
Space/Area #	Space/Area Name	208	208	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Corner Station	Provided Throughout UON →																															
L-100	Laser and Vacuum Equipment Area	120	208		X	X		X	X				X		X	X	X				X	X	0.1		X	X				X		
O-101	Mechanical/Utilities Equipment Room	208 & 480						X	X				X		X	X	X			X	X			X		X						
O-101	Lobby/Reception Area	X						X	X				X		X																	
O-102	Site Manager's Office	X						X	X																							
O-103	Conference Room	X	208			X	X	X	X																							
O-104	Staff Offices	X						X	X																							
O-105	Control Room	X	X	X		X	X	X	X							X							0.05			X						
O-106	Change/Smock Room	X							X				X		X							X	0.05									
O-107	Experimental Equipment Area	X	X			X	X	X	X				X		X	X	X					X										
O-108	Testing Area	X	X			X	X	X	X				X		X	X	X					X										
O-109	Electronics Shop	208 & 480	X			X	X	X	X				X		X	X	X					X				X						
O-110	Mechanical Shop	208 & 480				X			X				X		X	X	X					X				X						
O-111	Inspection Area	X				X		X	X				X		X	X	X									X					X	
O-112	Cleaning Area	208							X				X		X	X	X				X	X	0.05			X					X	
O-113	Airlock/Anteroom	X							X				X		X	X	X					X	0.05									
O-114	Clean Room	X	X			X	X	X	X							X						X	0.1			X						
O-115	Active Storage	X																								X						
O-116	Long Term Storage	X																								X						
A117	Receiving and Shipping	X							X				X		X		X					X			X						X	
A118	Data Storage	X				X	X	X	X																							
A119																																
Mid Station					X			X					X																			
M-100	Vacuum Equipment Area	120	208				X	X	X	X	X		X		X	X	X				X	X	0.1			X	X			X		
M-101	Mechanical/Utilities Equipment Room	X						X	X	X	X		X		X	X	X			X	X			X		X	X					
End Station					X			X					X																			
E-100	Vacuum Equipment Area	120	208				X	X	X	X	X		X		X	X	X				X	X	0.1			X	X			X		
E-101	Mechanical/Utilities Equipment Room	X						X	X	X	X		X		X	X	X			X	X			X		X	X					
Beam Tube Enclosure		208						X	X	X	X											X	0.01			X			X			
Chiller Plant		208 & 480			X			X	X	X			X		X							X				X	X	X				X

6.11 Interface with Interferometer, Vacuum Equipment, and Beam Tube Systems

System, Subsystem, or Component	Electrical					Comm.				Mechanical										Handling											
	Facility Power	Technical Power	UPS	Lightning Ground	Instrumentation Ground	Technical Ground	Facility Ground	Ethernet/LAN	Telephone	Wireless Transceiver	Public Address System	Facility Grnd.	Potable Water	Sewage	Drainage	Clean/Dry Instrument Air	Shop Air	Nitrogen Gas	Dionized Water	Natural Gas	Exhaust Vents	Positive Pressure	Hose Bibs for Washdown	House Cleaning Vacuum Ports	Fire Extinguishers	Fire Suppression	Fire Detection and Alarm	Particulate Monitoring	Bridge Cranes	Mono Rails	
Interferometer System																															
Control and Data Acquisition System	X				X		X																								
Lasers	X				X							X																			
Course Alignment Lasers/Optics	X				X																										
Vacuum Equipment System																															
Test Mass Chambers																								X						X	
Beam Splitter Chambers																							X							X	
Horizontal Access Modules																							X							X	
Monitor and Control Subsystem		X				X		X																							
Roughing Pumps	X					X						X																		X	
Cryo Pumps	X					X						X																		X	
Getter Pumps	X					X						X																		X	
Annulus Pumps	X					X						X																		X	
Valves	X					X						X											X							X	
Vent and Purge Subsystem	X					X						X																		X	
Bakeout Subsystem	X					X						X																		X	
Beam Tube System																															
Beam Tube Supports						X						X																			
Vacuum Pumps	X					X						X																			X

7. Verification and Testing

This section establishes the manner in which formal verification of the design performance requirements contained in Section 6 will be performed, and identifies additional testing beyond that required in Section 6.

7.1 Verification Methods

7.1.1 Analysis

Certain portions of the design effort will be of a character that is subject to analysis by computation, by application of experience and engineering judgment, or by adoption or correlation of test and/or performance data documented on other similar projects. It is mandatory that such analyses be documented for the LIGO Project in a manner readily understood by other engineers versed in the subject matter. Such documentation will indicate the source(s) if basic data was used, the method of computation or the formulas used, the step-by-step analytical process used, and the conclusion.

7.1.2 Inspection

Inspection is the visual determination of an item's qualitative or quantitative properties such as tolerances, finishes and identification.

7.1.3 Demonstration

Demonstration is the determination of qualitative and quantitative properties and performance of an item, and involves proof-by-doing without use of external resources. It is normally accomplished in conjunction with a test activity.

7.1.4 Standard Test

The standard test determines the qualitative and quantitative properties and performance according to standard test specifications and procedures specified in applicable accepted standards, manuals, regulations and/or codes.

7.1.5 Specific Test

The specific test determines the qualitative and quantitative properties and performance according to nonstandard test specifications and procedures. Specifications will include requirements, procedures, and plans for specific tests.

7.1.6 Test Significance

Where test results, experience, or judgment indicates that an item's malfunction could significantly impact performance of real property facilities and equipment, or results in unsafe conditions for users, operators or maintainers, that item will be subject to corrective action.

7.2 Requirements and Procedures

Special test requirements and procedures as well as standard inspection and test procedures necessary to meet the verification requirements in 7.3, 7.4, and 7.5 will be developed. Necessary special instructions relative to tests and inspections will be identified. Materials and certain equipment, as well as pavement and concrete mix designs, will also be identified within the construction specification as items to be submitted for review by the Construction Manager and approved by the A-E's Engineer..

7.3 Mechanical

7.3.1 Testing, Adjusting and Balancing of Building Systems

Testing and balancing of building HVAC and Hydronic systems will be conducted by firms certified by Associated Air Balancing Council (AABC) in those testing and balancing disciplines similar to those required for this project.

7.3.2 Clean Room Systems

Testing and balancing of clean room air systems will be conducted by firms certified by Associated Air Balancing Council (AABC) and will have a minimum of five previous test completion on similar clean rooms.

7.3.3 HEPA Filters

Field certification tests on installed HEPA filters will be performed in accordance with IES-RP-CC-006-84-T, "Ambient Particle Aerosol Challenge and Air Particle Counter - Downstream Filter Scan Test Method."

7.3.4 Fire Protection

The Sprinkler system will be tested in accordance with NFPA 13A.

7.4 Electrical Tests

All test results will be recorded and submitted in formal documentation for review and approval.

7.4.1 Grounding

Facility grounding tests will be conducted in accordance with the recommendations in IEEE Std 81-1983 and IEEE Std 81.2-1991.

7.4.2 New Equipment

New equipment will be tested for operation as recommended by the manufacturer and UL 674.

7.4.3 Short Circuits

Equipment and conductors rated at 600V and less will be tested to ensure that the wiring system and equipment is free from short circuits and from grounds other than required grounds.

7.4.4 Continuity

All wiring will be tested for conductor continuity.

7.4.5 Insulation Resistance

All new conductors will be tested for an insulation resistance value of 1 megohm or greater, with respect to the nearest grounded metal.

7.4.6 Power Cables

Conduct tests of 5 kV and higher voltage power cables as follows:

- A. Cable manufacturer will furnish certified test reports per AEIC CS 5, CS 6 and UL 1072, for all tests performed.
- B. The completed cable will be tested for Corona Discharge and will comply with the AEIC requirements.
- C. High voltage DC field testing before and after installation using test voltage(s) as recommended by AEIC S-68-516, CS 5 and CS 6.

7.4.7 Isolation Resistance

The grounding subsystems isolation resistance will be tested for 1 megohm isolation between each other.

7.4.8 Electric Power Characteristics

To ensure compliance with 6.6.7, the A-E will take required measurements of site-available power and submit a formal report for review and approval.

7.4.9 Phase Rotation

Phase rotation will be per NEMA. All panels, 3-phase outlets, 3-phase equipment, motors, etc. will be tested for correct rotation.

7.4.10 Alarm Systems

All alarm systems will be tested for each alarm condition.

7.4.11 Controls and Interlocks

All controls and interlock circuits will be tested for proper and safe performance.

7.4.12 Motor Insulation

Motor insulation resistance will be measured before energizing per IEEE Standard 43.

7.4.13 Illumination

Lighting and illumination compliance with 6.6.5, will be determined by field measurement.

7.5 Architectural

7.5.1 Painting

All shop and field painting will be inspected and approved by a National Association of Corrosion Engineers (NACE) certified inspector.

8. Abbreviations

A	Ampere
AABC	Associated Air Balancing Council
AASHTO	American Association of State Highway and Transportation Officials
ABS	Acrylonitrile - Butadiene - Styrene
A/C	Air Conditioning
ACCA	Air Conditioning Contractors of America
Ach/hr	Air Changes per hour
ACI	American Concrete Institute
ADA	Americans with Disabilities Act
ADC	Air Diffuser Council
A-E	Architect - Engineer
AECS	Automated Entry Control System
AEIC	Association of Edison Illuminating Companies
AFBMA	ANSI/Fan Bearing Manufacturers Association
AFF	Above Finished Floors
AISC	American Institute of Steel Construction
AMCA	Air Moving and Conditioning Association
AMP	Ampere
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASPE	American Society of Plumbing Engineers
ASSE	American Society of Structural Engineers
ASTM	American Society of Testing Materials
AWG	American Wire Gauge
AWS	American Weld Society
AWWA	American Water Works Association
BHMA	Builders Hardware Manufacturers Association
°C	Degrees Centigrade
CAGI	Compressed Air and Gas Institute
CCR	Clothing Change Room
CECER-EM	Corps of Engineers Civil Engineering Regulation - Engineering Maintenance
CFC	Chlorofluorocarbon
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
Ch	Chapter
CISCA	Ceilings and Interior Systems Construction Association

cm	Centimeters
CMAA	Crane Manufacturers Association of America
CRI	Color Rendering Index
CS	Communication System
CTI	Cooling Tower Institute
dB	Decibel
DC/dc	Direct Current
DDC	Direct Digital Control
DDCP	Direct Digital Control Panel
DL	Dead Load
DOP	Diocetylphalate
E	Seismic Load
EA	Environmental Assessment
EER	Electrical Equipment Room
EES	Earth Electrode Subsystem
EMC	Electromagnetic Compatibility
EMCS	Energy Management Control System
EMI	Electromagnetic Interference
EMT	Electric Metallic Tubing
EPR	Ethylene Propylene Rubber
ESR	Equipment Storage Room
ESS	Electronic Security System
ETL	Engineering Technical Letter
EX	Exceptions
°F	Degrees Fahrenheit
fc	Footcandles
FCC	Federal Communications Commission
FDC	Facility Design Criteria
FED-STD	Federal Standard
FEMA	Federal Emergency Management Agency
FIP	Field Interface Panels
FMEC	Factory Mutual Engineering Corporation
°F _{db}	Degrees Fahrenheit-dry bulb
fpm	Feet per Minute
ft	Foot
FTM	Federal Test Manual
°F _{wb}	Degrees Fahrenheit-wet bulb
g	Gravity Constant (Earth)
GFE	Government Furnished Equipment
GHe	Gaseous Helium
GHz	Gigahertz
GN ₂	Gaseous Nitrogen
gpm	Gallons per Minute
gr/lbda	Grams per Pound Dry Air

HEPA	High Efficiency Particulate Air
Hg	Mercury
hr	Hours
HVAC	Heating, Ventilation and Air Conditioning
Hz	Hertz
ICEA	Insulated Cable Engineering Association
ICBO	International Conference of Building Officials
IEEE	Institute of Electrical and Electronics Engineers
IES	Illuminating Engineering Society
IES	Institute of Environmental Science
in	Inches
ISA	Instrument Society of America
KHz	Kilo-hertz
km	Kilometers
kV	Kilo-volt
kVA	Kilo-volt-Ampere
LL	Live Load
LPS	Low Pressure Sodium
Mdl	Model
MER	Mechanical Equipment Room
mg/ft ³	Milligram per cubic foot
mm	Millimeter
MPH	Miles per Hour
NACE	National Association of Corrosion Engineers
NACSEM	National COMSEC/EMSEC Information Memorandum
NACSIM	National COMSEC Information Memorandum
NAPHCC	National Association of Plumbing, Heating and Cooling Contractors
NEBB	National Environmental Balance Bureau
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NFC	National Fire Code
NFPA	National Fire Protection Association
NIBS	National Institute of Building Sciences
NIC	Not in Contract
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NLSC	National Life Safety Code
NPC	National Plumbing Code
O&M	Operations and Maintenance
OSHA	Occupational Safety and Health Act
OSR	Operations Support Room
ppm	Parts per million
ppmv	Parts per million by volume

psf	Pounds per Square Foot
psi	Pounds per Square Inch
psig	Pounds per Square Inch Gage
PVC	Polyvinyl Chloride
RF	Radio Frequency
RFI	Radio Frequency Interference
RPIE	Real Property Installed Equipment
SBC	Standard Building Code
SBCCI	Southern Building Code Congress International
SCFM	Standard Cubic Feet per Minute
sf	Square Feet
SJI	Steel Joist Institute
SMACNA	Sheet Metal Air Conditioning National Association
SSC	Systems Security Contractor
SSPC	Steel Structures Painting Council
STC	Sound Transmission Class
TAB	Testing and Balance
TBD	To Be Determined
TBR	To Be Revised
THD	Total Harmonic Distortion
UBC	Uniform Building Code
UFC	Uniform Fire Code
UL	Underwriters Laboratory
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code
UPS	Uninterruptible Power System/Supply
V	Volts
VAC	Volts Alternating Current
VOC	Volatile Organic Compounds
Vol	Volume
WL	Wind Load
w.c.	Water Column
w.g.	Water Gauge

Appendix A

Facility Programing Sheets

Facility Program

General

Site: Hanford, WA
Building: Corner Station - LVEA
Space/Area Number: L100
Area/Space Name: Laser Vacuum Equipment Area
Space Function: house laser vacuum equipment
Finish Floor Level: 00.00

Adjacencies

Direct: Control Room, Cleaning / Inspection Area & Change/Smock room
Indirect: Observation room, Experimental & Testing areas

Requirements

Space/Occupancy

Occupants: 3
Approx SF: 64000
Ceiling Height: vari'-es

Electrical/Mechanical

Fire Supression:
Fire Detection:
Humidity: 40-50 +/- 5
Temperature: 68-72
Clean: 50000
Lighting Level: 50fc

Special Requirements: 1) surfaces seamless & smooth; 2) flooring resilient & impact resistant
 3) cranes provided for equipment removal & replacement

Remarks: 1) accessibility to equipment & emergency exits

General

Site: Hanford, WA
Building: Corner Station - LVEA
Space/Area Number: L101
Area/Space Name: Mechanical/Utilities Equipment Room
Space Function: houses HVAC & electrical equipment for LVEA
Finish Floor Level: 00.00

Adjacencies

Direct: LVEA
Indirect: Administration/shop facility

Requirements

Space/Occupancy

Occupants: 0
Approx SF: 10000
Ceiling Height: vari'-es

Electrical/Mechanical

Fire Supression:
Fire Detection:
Humidity:
Temperature:
Clean: 0
Lighting Level: 50fc

Special Requirements: Isolated from LVEA for sound & vibration

Remarks:

Facility Program

General

Site: Hanford, WA
Building: Corner Station - Ops Support Bldg
Space/Area Number: O101
Area/Space Name: Lobby - Reception
Space Function: Main entrance to facility for employees & visitors
Finish Floor Level:

Adjacencies

Direct: Conference room, offices, employee locker room, & toilet rooms
Indirect: Control room, change/smock room, computer rooms, shops

Special Requirements:

Remarks: 1) Entrance & reception areas to accommodate large groups; 2) to be pleasant & open; 3) accommodate displays & announcements; 4) seating area for small groups; 5) pleasant atmosphere for both receptionist & visitors; 6) clear view of entrance from either desk or built-in counter

Requirements

Space/Occupancy

Occupants: 1
Approx SF: 300
Ceiling Height: 8'-0"

Electrical/Mechanical

Fire Suppression:
Fire Detection:
Humidity: (N)
Temperature: 68-72deg
Clean: (N)
Lighting Level: 75-100fc

General

Site: Hanford, WA
Building: Corner Station -Ops Support Bldg
Space/Area Number: O102
Area/Space Name: Site Manager's Office
Space Function: office for site manager
Finish Floor Level: 00.00

Adjacencies

Direct: Lobby/reception, control room, staff offices
Indirect: Computer rooms, cleanroom, shops, toilets

Special Requirements:

Remarks: 1) provide desk & chair, credenza, lateral file cabinet, bookcase, tackboard/chalkboard, small conference table & chairs; 2) include telephone & PC connection

Requirements

Space/Occupancy

Occupants: 1
Approx SF: 250
Ceiling Height: 8'-0"

Electrical/Mechanical

Fire Suppression:
Fire Detection:
Humidity: (N)
Temperature: 68-72deg
Clean: (N)
Lighting Level: 100fc

Facility Program

General

Site: Hanford, WA
Building: Corner Station -Ops Support Bldg
Space/Area Number: O103
Area/Space Name: Conference room
Space Function: conference/assembly/meeting area for staff & visitors
Finish Floor Level: 00.00

Adjacencies

Direct: Lobby/reception, site manager's office, staff offices
Indirect: Toilets, lunch/breakroom

Special Requirements: 1) display capabilities for mutli-media presentations & tele-video conferencing; 2) variable ligthing control
3) include telephone & PC connections

Remarks: 1) conference seating for staff of 10-15; 2) conference seating for visitors & staff of 20
3) presentation seating for tour groups of 40; 4) provide capabilities/access to refreshments

Requirements

Space/Occupancy

Occupants: 40
Approx SF: 600
Ceiling Height: 10'-0"

Electrical/Mechanical

Fire Supression:
Fire Detection:
Humidity: (N)
Temperature: 68-72deg
Clean: (N)
Lighting Level: 100fc - vaiable

General

Site: Hanford, WA
Building: Corner Station -Ops Support Bldg
Space/Area Number: O104
Area/Space Name: Staff offices
Space Function: house scientific staff (3), visiting scientists & interns (9)
Finish Floor Level: 00.00

Adjacencies

Direct: Control room, computer room, LVEA, cleanroom, & experimental testing areas
Indirect: Lobby, toilets & lunch/breakroom

Special Requirements: 1) furniture includes desk, chair, bookcase, lateral file per occupant; 2) tack/chalkboard per office
3) include telephone & PC connection

Remarks: 1) offices sized to accommodate 4 people each

Requirements

Space/Occupancy

Occupants: 12
Approx SF: 80
Ceiling Height: 8'-0"

Electrical/Mechanical

Fire Supression:
Fire Detection:
Humidity: (N)
Temperature: 68-72deg
Clean: (N)
Lighting Level: 100fc

Facility Program

General

Site: Hanford, WA
Building: Corner Station -Ops Support Bldg
Space/Area Number: O105
Area/Space Name: Control Room
Space Function: Data acquisition & monitoring equipment from LVEA, remote buildings, entry
Finish Floor Level: 00.00

Adjacencies

Direct: LVEA, change/smock room, computer room, UPS room
Indirect: Site manager, offices, experimental equipment & testing areas, lunch/breakroom

Special Requirements: 1) Access floor for cable management; 2) CCTV monitors
3) EMCS for climate control; 4) double door wide access
5) desktop workstations

Remarks: 1) Observation window to LVEA & to change/smock room
2) possible alternate location on 2nd level for better direct observation

Requirements

Space/Occupancy

Occupants: 2
Approx SF: 600
Ceiling Height: 10'-0"

Electrical/Mechanical

Fire Supression:
Fire Detection:
Humidity: (Y)
Temperature: 68-72deg
Clean: (N)
Lighting Level: 35-50fc

General

Site: Hanford, WA
Building: Corner Station -Ops Support Bldg
Space/Area Number: O106
Area/Space Name: Change / Smock Room
Space Function: change area entry to LVEA
Finish Floor Level: 00.00

Adjacencies

Direct: LVEA, control room
Indirect: Computer rooms, experimental & testing areas, toilets, lunch/breakroom

Special Requirements: 1) Clothes racks for smocks, new booty dispensers, hampers for soild booties & smocks
2) benches for dressing;

Remarks:

Requirements

Space/Occupancy

Occupants: 0
Approx SF: 120
Ceiling Height: 8'-0"

Electrical/Mechanical

Fire Supression:
Fire Detection:
Humidity: (N)
Temperature: 68-72deg
Clean: 50000
Lighting Level: 75-100fc

Facility Program

General

Site: Hanford, WA
Building: Corner Station -Ops Support Bldg
Space/Area Number: O107
Area/Space Name: Computer Room
Space Function: Data acquisition, contains computers, servers & processors, tape storage - short
Finish Floor Level: 00.00

Adjacencies

Direct: Control room, computer archives, offices, lounge/breakroom, UPS room
Indirect: Receiving & shipping, manager,

Special Requirements: 1) Access floor system; 2) Observation window to Control Room
3) Fireproof tape storage

Remarks: 1) Provide work desk / reference area

Requirements

Space/Occupancy

Occupants: 2
Approx SF: 500
Ceiling Height: 8'-0"

Electrical/Mechanical

Fire Suppression:
Fire Detection:
Humidity: (Y)
Temperature: 68-72deg
Clean: (N)
Lighting Level: 50fc

General

Site: Hanford, WA
Building: Corner Station -Ops Support Bldg
Space/Area Number: O108
Area/Space Name: Computer Archives
Space Function: Tape storage - long term
Finish Floor Level: 00.00

Adjacencies

Direct: Control room, computer archives, offices, lounge/breakroom
Indirect: Receiving & shipping, manager

Special Requirements: 1) Access floor system
2) Fireproof tape storage

Remarks: 1) Provide work desk / reference area

Requirements

Space/Occupancy

Occupants: 0
Approx SF: 300
Ceiling Height: 8'-0"

Electrical/Mechanical

Fire Suppression:
Fire Detection:
Humidity: (Y)
Temperature: 68-72deg
Clean: (N)
Lighting Level: 50fc

Facility Program

General

Site: Hanford, WA
Building: Corner Station -Ops Support Blg
Space/Area Number: O109
Area/Space Name: Experimental Equipment Area
Space Function: Data acquisition & monitoring equipment from LVEA,
Finish Floor Level: 00.00

Adjacencies

Direct: Control room, testing area,
Indirect: Toilets & lunch/breakroom, LVEA, cleaning area, cleanroom, shops, inspection, loading

Special Requirements: 1) observation windows
2) laboratory workbenches

Remarks:

Requirements

Space/Occupancy

Occupants: 3
Approx SF: 1600
Ceiling Height: 12'-0"

Electrical/Mechanical

Fire Supression:
Fire Detection:
Humidity: (Y)
Temperature: 68-72deg
Clean: (N)
Lighting Level: 100fc

General

Site: Hanford, WA
Building: Corner Station -Ops Support Blg
Space/Area Number: O110
Area/Space Name: Testing Area
Space Function: Testing of components prior to installation in chambers & interferometers
Finish Floor Level: 00.00

Adjacencies

Direct: Experimental equipment area, shops, inspection, cleaning area, loading dock
Indirect: Toilets & lunch/breakroom, LVEA, cleanroom

Special Requirements: 1) vacuum system; 2) compressed air
3) clean air system; 4) monorail & crane; 5) exhaust heat from bakeout equipment

Remarks:

Requirements

Space/Occupancy

Occupants: 3
Approx SF: 1200
Ceiling Height: 10'-0"

Electrical/Mechanical

Fire Supression:
Fire Detection:
Humidity: (Y)
Temperature: 68-72deg
Clean: (N)
Lighting Level: 100fc