APPENDIX 2A

Engineering

APPENDIX 2A

Engineering

The GWF Tracy project will be designed for high reliability and efficiency. A detailed project description is provided in Section 2.0. The engineering standards and requirements are provided in Appendix 2A 1-6. The details of the transmission system design, including information on the safety and reliability of the transmission system, are provided in Section 3.0 (Electric Transmission).

A description of the project and its design and operation can be found in Section 2.0 (Project Description). Design and engineering information for the project is located throughout this Application for Certification (AFC), as follows:

Power generation	Section 2.2.2 (Process Description), Section 2.2.3 (Power Plant Cycle)
Water supply system	Section 2.2.7 (Water Supply and Use)
Atmospheric emission control system	Section 2.2.10 (Emissions Control and Monitoring), and Section 5.1 (Air Quality).
Waste disposal system	Section 2.2.8 (Waste Management) and Section 5.14 (Waste Management).
Noise abatement	Section 5.7 (Noise).
Switchyard/transformer systems	Section 2.2.5 (Major Electrical Equipment and Systems) and Section 3.0 (Electric Transmission).
Transmission system design	Section 3.0 (Electric Transmission) and Appendix 2A.
Reliability	Section 2.4 (Facility Reliability).
Efficiency	Section 2.2.2 (Process Description) and Figures

Information regarding design measures to ensure safe facility operation is contained in Section 2.3 (Facility Safety Design). Applicable engineering laws, ordinances, regulations, and standards (LORS) are summarized in Section 2.5 (Facility Design Laws, Ordinances, Regulations, and Standards), Table 2-6, and Appendix 2A. Throughout this AFC and Appendix 2A, references to the Uniform Building Code should be understood to be inclusive of the corresponding provisions of the California Building Code.

A geotechnical investigation of the project site was conducted, including foundation core borings, and can be found in Section 5.4 (Geological Hazards & Resources).

Additional engineering information, including information on mechanical engineering, electrical engineering, civil engineering, structural engineering, system controls, and an equipment summary, is contained in Appendix 2A.

GWF Tracy will comply with all applicable LORS. A summary of the LORS is provided in Section 2.5 (Facility Design Laws, Ordinances, Regulations, and Standards) and Table 2-6.

Contact information for the pertinent agency is provided below.

Agency	Contact/Title	Telephone
San Joaquin County Community Development Department 1810 E. Hazelton Avenue Stockton, CA 95205-6298	Community Development Director	(209) 468-3121
City of Tracy Department of Engineering Services 520 Tracy Boulevard Tracy, CA 95376	Mr. William Reeds Director of Development and Engineering Services	(209) 831-4600

APPENDIX 2A.1

Foundation and Civil Engineering Design Criteria

APPENDIX 2A.1

Foundation and Civil Engineering Design Criteria

1.0 Introduction

The design, engineering, procurement, and construction activities on the project will be in accordance with various predetermined standards and project-specific practices. This appendix summarizes the civil engineering codes and standards, design criteria, and practices that will be used during design and construction. These criteria form the basis of the design for the foundations and civil systems of the project. More specific design information will be developed during the detailed design phase to support equipment procurement and construction specifications. It is not the intent of this appendix to present the detailed design information for each component and system, but rather to summarize the codes, standards, and general criteria that will be used.

Section 2.0 summarizes the applicable codes and standards, and Section 3.0 includes the general criteria for foundations, design loads, and sitework.

2.0 Design Codes and Standards

2.1 General Requirements

The design and specification of work will be in accordance with all applicable laws and regulations of the Federal Government, the State of California, and the applicable local codes and ordinances. Except where noted otherwise, the latest issue of all codes and standards, including addenda, in effect at the start of the project will be used. The codes and standards, including all addenda, in effect at the time of purchase will be used for material and equipment procurement.

A summary of the codes and the standards to be used in the design and construction follows:

- Seismic standards and criteria will follow the California Building Code (CBC).
- Specifications for materials will follow the standard specifications of the American Society for Testing and Materials (ASTM) and the American National Standards Institute (ANSI), unless noted otherwise.
- Field and laboratory testing procedures for materials will follow ASTM standards.
- Design and placement of structural concrete and reinforcing steel will be in accordance with the codes, guides, and standards of the American Concrete Institute (ACI) and the Concrete Reinforcing Steel Institute (CRSI).

- Specifications for materials for roads will follow the State of California Department of Transportation (Caltrans) Standard Specifications.
- Design and construction of roads will follow the American Association of State Highway and Transportation Officials (AASHTO) and Caltrans standards.
- Design and construction of the sanitary sewer system will conform to the Uniform Plumbing Code (UPC).
- Design and construction will conform to federal and California Occupational Safety and Health Administration (OSHA and CAL-OSHA) requirements.

Other recognized standards will be used where required to serve as guidelines for the design, fabrication, and construction. Where no other code or standard governs, the CBC, 2007 Edition, will govern.

2.2 Government Rules and Regulations

The following laws, ordinances, regulations, and standards (LORS) are applicable to the civil engineering design and construction. In cases where conflicts between cited codes (or standards) exist, the requirements of the more stringent code will govern.

2.2.1 Federal

- Title 29, Code of Federal Regulations (CFR), Part 1910, Occupational Safety and Health Standards.
- Title 29, CFR, Part 1926, National Safety and Health Regulations for Construction.
- Walsh-Healy Public Contracts Act (Public Law [PL] 50-204.10).
- National Pollutant Discharge Elimination System (NPDES) (US Environmental Protection Agency [EPA]).

2.2.2 State

- California Building Code.
- Business and Professions Code Section 6704, et seq.; Sections 6730 and 6736. Requires state registration to practice as a Civil Engineer or Structural Engineer in California.
- Labor Code Section 6500, et seq. Requires a permit for construction of trenches or excavations 5 feet or deeper into which personnel have to descend. This also applies to construction or demolition of any building, structure, false work, or scaffolding that is more than three stories high or equivalent.
- Title 24, California Code of Regulations (CCR). Adopts current edition of CBC as minimum legal building standards.
- Caltrans, Standard Plans & Specifications.
- Title 8, CCR Section 1500, et seq.; Section 2300, et seq.; and Section 3200, et seq. Describes general construction safety orders, industrial safety orders, and work safety requirements and procedures.

- Regulations of the following state agencies as applicable:
  - Department of Labor and Industry Regulations.
  - Bureau of Fire Protection.
  - Department of Public Health.
  - Water and Power Resources.
- Vehicle Code, Section 35780, et seq. Requires a permit from Caltrans to transport heavy loads on state roads.

2.2.3 Local

- California Building Code, 2007 edition.
- City of Tracy Engineering Services – Storm Water Management Plan

2.2.4 Engineering Geology Codes and Standards

The design and specification of work will be in accordance with all applicable laws and regulations of the Federal Government, the State of California, and the applicable local codes and ordinances.

The site development activities will require certification during and following construction. The Geotechnical Engineer and Engineering Geologist will certify the placement of fills and adequacy of the site for structural improvements in accordance with the CBC. Additionally, the Engineering Geologist will present findings and conclusions pursuant to PRC Section 25523 (a) and (c) 20 CCR Section 1752 (b) and (c).

The following laws, ordinances, codes, and standards have been identified as applying to engineering geology design and construction. In cases where conflicts between cited codes (or standards) exist, the requirements of the more conservative code will be met.

2.2.4.1 Federal

- None are applicable.

2.2.4.2 State —California Building Code

The Warren-Alquist Act (PRC Section 25000, et seq.) and the CEC Siting Regulations (20 CCR, Chapter 2) require that Applications for Certification address geologic and seismic issues. Detailed geologic and seismic information must be provided with respect to safety and reliability concerns and environmental impacts.

The California Environmental Quality Act (CEQA) (PRC Section 21000, et seq.) and the CEQA Guidelines also require that potential significant effects, including geologic hazards, be identified and a determination made as to whether they can be substantially reduced.

2.2.4.3 County

California State Planning Law, Government Code Section 65302, requires each city and county to adopt a general plan, consisting of nine mandatory elements, to guide its physical development. Section 65302 (f) requires that a seismic safety element be included in the general plan. Seismic and geologic hazard plans and regulations are often addressed under the seismic safety elements of general plans or in local building and grading ordinances.

2.2.4.4 Industry Codes and Standards

In addition to the California Codes discussed above, other laws, standards, and ordinances, which typically pertain to engineering geology, include the following:

- California Business and Professions Code Section 7835. Requires registration for geologists (including engineering geologists) who practice for others.

The codes and industry standards used for design, fabrication, and construction will be the codes and industry standards, including all addenda, in effect as stated in equipment and construction purchase or contract documents. Where no other standard or code governs, the CBC will be used.

2.3 Industry Codes and Standards

2.3.1 American Association of State Highway and Transportation Officials (AASHTO)

- A Policy on Geometric Design of Highways and Streets.

2.3.2 American Concrete Institute (ACI)

- ACI 117—Standard Specification for Tolerances for Concrete Construction and Materials.
- ACI 211.1—Standard Practice for Selecting Proportions of Normal, Heavyweight, and Mass Concrete.
- ACI 301—Specifications for Structural Concrete for Buildings.
- ACI 302.1R—Guide for Concrete Floor and Slab Construction.
- ACI 304R—Guide for Measuring, Mixing, Transporting, and Placing Concrete.
- ACI 305R—Hot Weather Concreting.
- ACI 306R—Cold Weather Concreting.
- ACI 308—Standard Practice for Curing Concrete.
- ACI 309R—Guide for Consolidation of Concrete.
- ACI 311AR—Guide for Concrete Inspection.
- ACI 318—Building Code Requirements for Reinforced Concrete.
- ACI 318.1—Building Code Requirements for Structural Plain Concrete.
- ACI 347R—Guide to Formwork for Concrete.

2.3.3 American Society for Testing and Materials (ASTM)

- ASTM A82—Standard Specification for Steel Wire, Plain, for Concrete Reinforcement.
- ASTM A116—Standard Specification for Zinc-Coated (Galvanized) Steel Woven Wire Fence Fabric.
- ASTM A121—Standard Specification for Zinc-Coated (Galvanized) Steel Barbed Wire.

- ASTM A185—Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement.
- ASTM A392—Standard Specification for Zinc-Coated Steel Chain-Link Fence Fabric.
- ASTM A615—Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.
- ASTM C31—Standard Practice for Making and Curing Concrete Test Specimens in the Field.
- ASTM C33—Standard Specification for Concrete Aggregates.
- ASTM C39—Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
- ASTM C76—Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe.
- ASTM C94—Standard Specification for Ready-Mixed Concrete.
- ASTM C109—Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2 in. or 50 mm Cube Specimens).
- ASTM C136—Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
- ASTM C138—Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete.
- ASTM C143—Standard Test Method for Slump of Hydraulic Cement Concrete.
- ASTM C150—Standard Specification for Portland Cement.
- ASTM C172—Standard Practice for Sampling Freshly Mixed Concrete.
- ASTM C231—Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.
- ASTM C260—Standard Specification for Air-Entraining Admixtures for Concrete.
- ASTM C289—Standard Test Method for Potential Reactivity of Aggregates (Chemical Method).
- ASTM C443—Standard Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets.
- ASTM C478—Standard Specification for Precast Reinforced Concrete Manhole Sections.
- ASTM C494—Standard Specification for Chemical Admixtures for Concrete.
- ASTM C586—Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (Rock Cylinder Method).
- ASTM C618—Standard Specification for Coal Fly Ash and Raw or Calcinated Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete.

- ASTM C1064—Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete.
- ASTM C1107—Standard Specification for Packaged Dry, Hydraulic Cement Grout (Nonshrink).
- ASTM D422—Standard Test Method for Particle-Size Analysis of Soils.
- ASTM D698—Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft (600 kN-m/m)).
- ASTM D1556—Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.
- ASTM D1752—Standard Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction.
- ASTM D2216—Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock.
- ASTM D2922—Standard Test Methods for Density of Soil and Soil Aggregate in Place by Nuclear Methods (Shallow Depth).
- ASTM D3017—Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth).
- ASTM D3034—Standard Specification for Type PSM Poly (Vinyl Chloride) (PVC) Sewer Pipe and Fittings.
- ASTM D3740—Standard Practice for Evaluation of Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction.
- ASTM D4318—Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
- ASTM E329—Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction.

2.3.4 Concrete Reinforcing Steel Institute (CRSI)

- Manual of Standard Practice.

2.3.5 International Association of Plumbing and Mechanical Officials

- UPC—Uniform Plumbing Code.

2.3.6 International Conference of Building Officials

- CBC—California Building Code.

3.0 Civil Design Criteria

3.1 Foundations

3.1.1 General

Geotechnical exploration, testing, and analysis determine the most suitable bearing methods for foundations. Criteria will be established to permit design of the most economical foundation compatible with the life expectancy and service of the structure.

A summary of subsurface investigations, laboratory testing programs and a geotechnical assessment of the proposed site are presented in the Preliminary Geotechnical Investigation prepared by Hultgren – Tillis Engineers, dated June 26, 2001.

3.1.2 Foundation Design Criteria

Allowable settlements for all foundations (based on predicted elastic or short-term, and consolidation or long-term settlements) will be limited as follows:

Major and minor foundations except as otherwise indicated:

- Total settlement: 1.5 inches.
- Differential settlement: 0.1 percent between adjacent foundations.

Large field erected tanks:

- Total settlement: 6.0 inches.
- Differential settlement: 3.0 inches.

Foundations for all critical structure and equipment will be supported on reinforced concrete mat foundations. Noncritical or lightly loaded structures and equipment will be founded on individual spread footings. The design of reinforced concrete foundations will satisfy the requirements of ACI 318.

Spread footings will have a minimum width of 3 feet, and a minimum width of 2 feet will be provided for wall footings. The bottom of footings will be located a minimum of 12 inches below finished grade.

Detailed foundation design criteria, including allowable bearing pressures, will be developed based on the results of additional subsurface investigations performed during the detailed design phase of the project. Allowable bearing pressures will include a safety factor of at least 3 against bearing failures.

3.1.3 Equipment Foundations

Each piece of equipment will be supplied with a reinforced concrete foundation suitable to its operation. Where the equipment could induce excessive vibration, the foundation will be provided with adequate mass to dampen vibratory motions. Special consideration will be given to vibration and stiffness criteria where specified by an equipment manufacturer. Equipment located within an enclosed building with a grade slab will generally be placed on a concrete pad that is raised above the grade slab to keep the equipment off the floor surface.

Minimum temperature and shrinkage reinforcing steel will be provided for equipment foundations unless additional reinforcement is required for the equipment loads. Anchor bolts designed to develop their yield strength will be provided for critical equipment. For noncritical or lightly loaded equipment, concrete expansion anchors may be used to secure equipment to foundations.

3.1.4 Rotating Equipment Foundations

Dynamic behavior will be considered in the design of foundations subjected to significant rotating equipment loads, such as foundations for the steam turbine and the boiler feedwater pumps. A dynamic analysis will be performed to determine the natural frequencies and dynamic responses of the foundation. To account for soil and structure interaction, geotechnical data will be used to determine the soil stiffnesses and damping coefficients used in the dynamic analysis.

Dynamic responses will satisfy the equipment manufacturer's criteria and/or industry standards in terms of maximum velocity/displacement amplitudes that are considered acceptable for machine and human tolerances. To avoid resonance during machine operation, the resonant frequency of the foundation will typically be less than 80 percent or greater than 120 percent of the machine operating speed.

3.2 Design Loads

3.2.1 General

Design loads for structures and equipment foundations are discussed in Appendix J2 of the AFC. Design loads for pavements and buried items will be determined according to the criteria described below, unless the applicable building code requires more severe design conditions.

3.2.2 Wheel Loads

Loads exerted on roadway pavements, buried piping, electrical duct banks, and culverts will be reviewed and selected prior to design of the underlying items. As a minimum, these items will be designed for HS20 loadings in accordance with AASHTO Standard Specifications. Loadings exceeding the HS20 loadings will be considered where found applicable during the detailed design phase.

A surcharge load of 250 psf will be applied to plant structures accessible to truck traffic.

3.3 Site

3.3.1 Site Arrangement

The site arrangement will conform to all applicable laws, regulations, and environmental standards. The principal elements to be considered establishing the site arrangement include the physical space requirements and relationships dictated by each of the major plant systems and the constraints imposed by the physical size and existing topography of the site. Distances from the main plant to various systems will be minimized for economy. However, adequate clearance between various plant systems will be provided as needed for construction, operations, maintenance, fire protection, and adequate space for storm water drainage systems The plant will be configured to minimize construction costs and visual

impacts while remaining operationally effective. Routing for utility interconnections will be optimized as much as practical.

3.3.2 Site Preparation

Site preparation will consist of minimal clearing and grubbing for the area to the west of the existing simple cycle units, excavating soils to design grade, and preparing fill slopes and embankments designed so as to be stable and capable of carrying the anticipated loads from either equipment or structures.

Root mats or stumps, if any, will be removed to a depth of not less than 2 feet below existing grade, and holes will be refilled with compacted material suitable for embankment construction. Materials from clearing and grubbing operations will either be removed from the site or, if suitable, reused onsite.

3.3.3 Earthwork

Earthwork will consist of the removal, storage, and/or disposal of earth, sand, gravel, vegetation, organic matter, loose rock, boulders, and debris to the lines and grades necessary for construction. Material suitable for backfill will be stored in stockpiles at designated locations using proper erosion protection and control methods. Excess and unsuitable material will be removed from the site and disposed of at an acceptable location. If contaminated material is encountered during excavation, it will be disposed of in compliance with applicable federal, state, and local regulations.

Graded areas will be finished to be smooth, compacted, free from irregular surface changes, and sloped to drain. Cut and fill slopes for permanent embankments will be designed to withstand horizontal ground accelerations as defined by the CBC. For slopes requiring soil reinforcement to resist seismic loading, geogrid reinforcement will be used in fill areas and soil nails will be used in cut areas. Slopes for embankments will be no steeper than 2:1 (horizontal:vertical). Construction will be at the existing plant grade, which is fairly level; therefore, major cuts and fills are not anticipated.

Areas to be backfilled will be prepared by removing unsuitable material and rocks. The bottom of an excavation will be examined for loose or soft areas. Such areas will be excavated fully and backfilled with compacted fill.

Backfilling will be in layers of uniform, specified thickness. Soil in each layer will be properly moistened to facilitate compaction and achieve the specified density. To verify compaction, representative field density and moisture-content tests will be taken during compaction. Structural fill supporting foundations, roads, parking areas, etc., will be compacted to at least 95 percent of the maximum dry density as determined by ASTM D698. Embankments, dikes, bedding for buried piping, and backfill surrounding structures will be compacted to a minimum of 90 percent of the maximum dry density. General backfill placed in remote and/or unsurfaced areas will be compacted to at least 85 percent of the maximum dry density.

Where fills are to be placed on subgrades sloped at 6:1 (horizontal:vertical) or greater, keys into the existing subgrade may be provided to help withstand horizontal seismic ground accelerations.

The subgrade (original ground), subbases, and base courses of roads will be prepared and compacted in accordance with Caltrans standards. Testing will be in accordance with ASTM and Caltrans standards.

3.3.4 Site Drainage

The site drainage system will be designed to comply with all applicable federal, state, and local regulations.

Runoff from possible oil contamination areas, such as the lube oil storage area and transformer areas, will be contained and routed to an existing oil/water separator. After passing through the oil/water separator the effluent is routed to an onsite wastewater storage tank.

3.3.4.1 Storm Sewer System

The storm sewer system within the limits of the power block will consist of the existing system of drop inlets and storm drain pipes. An existing manhole located below the proposed new steam turbine step up transformer will be removed and relocated to the west side of the transformer. The new storm sewer system will include a combination of catch basins, manholes, and storm piping directing drainage to the new retention basin west of the air cooled condenser (ACC). All catch basin inlets will be constructed of cast-in-place or precast concrete with top grates. The minimum cover requirement, loading, and material selection for pipes will be adequate for HS20 truck loading.

3.3.4.2 Pre- and Post-Development Runoff Conditions

The existing simple cycle plant site currently consists of asphalt paved loop roads, aggregate surfacing around the power block and supporting facilities, and grass on the remaining perimeter. For the combined cycle conversion, the surfacing around the power block area will remain the same. Asphalt paved looped roads will be added around the air cooled condenser and supporting facilities. Aggregate surfacing will be used within the loop roads and grass along the remaining perimeter.

Currently storm water is collected through a combination of gradually sloped ditches, catch basins, storm drains, trench drains and culverts. This runoff will be rerouted using ditches, catch basins, storm drains, and culverts from the existing retention basin located on the west side of the simple cycle power block to the new storm water retention basin which will be located to the west of the ACC.

Erosion and Sedimentation Control

Erosion and sedimentation control will be provided to retain sediment onsite and prevent violations of water quality standards.

Permanent erosion and sedimentation control measures within the plant site will include the runoff collection system (inlets and drainage piping) and surfaced traffic areas. Final grading within the limits of the new facilities will include aggregate surfacing. These measures will minimize the possibility of any appreciable erosion, and the resulting sedimentation, occurring on the site.

Temporary erosion and sediment control measures which comply with the state and local requirements will be used during the construction phase.

3.3.5 Roads

Access to the plant site is provided by an existing public street to the west of the power block facility.

Access within the overall plant site will be provided by continuation of the loop road consisting of a 20 foot wide asphalt-paved road.

All new roads will be aggregate surfaced during the construction. Periodic watering or applications of a dust palliative material will be used for dust control.

The minimum radius to the inside edge of pavement (EOP) or aggregate surface at intersections of the roads will be 40 feet.

Because of the flat terrain of the plant site, grades for all roads will be minimal.

3.3.6 Fencing and Security

Modifications to the existing chain-link security fencing, topped with barbed wire, will be provided around the added combined cycle power plant facility site and other areas requiring controlled access.

Fencing heights will be in accordance with applicable codes and regulatory requirements.

A controlled access gate will be located at the main entrance to the secured area.

3.3.7 Sanitary Waste System

Sanitary waste is currently conveyed to a county-approved onsite sanitary waste disposal system consisting of a septic tank and a leaching field. The existing system will be adequate for final plant operations.

3.3.8 Spill Protection

Spill containment measures will be provided for chemical storage tanks and chemical additive/lube oil skid areas. All new chemical storage tanks will be provided with a containment structure with a volume equal to at least 110 percent of the tank capacity. In addition, all new outdoor containment structures will have a volume equal to the capacity of the tank, a fire protection flow of 250 gpm for ten minutes, and the volume of rainfall from the 25 year storm event. Concrete curbs will be provided for chemical additive/lube oil skid areas. Where required for protection of the containment structure, appropriate surface coatings will be provided.

3.4 Geotechnical Investigation

A Preliminary Geotechnical Investigation for the project has been performed by Hultgren-Tillis Engineers and is dated June 26, 2001.

APPENDIX 2A.2

Structural and Seismic Engineering Design Criteria

APPENDIX 2A.2

Structural and Seismic Engineering Design Criteria

1.0 Introduction

The project design, engineering, procurement, and construction activities will be in accordance with various predetermined standards and project-specific practices. This appendix summarizes the structural and seismic engineering codes and standards, design criteria, and practices that will be used during design and construction. These criteria form the basis for the project structural design work. More specific design information will be developed during detailed design to support equipment procurement and construction specifications. It is not the intent of this appendix to present the detailed design information for each component and system, but rather to summarize the codes, standards, and general criteria that will be used.

Section 2.0 summarizes the applicable codes and standards. Section 3.0 includes the general criteria for natural phenomena, design loads, materials, seismic design, and architecture. Section 4.0 describes the structural design methodology for structures and equipment. Section 5.0 addresses project hazard mitigation.

2.0 Design Codes and Standards

2.1 General Requirements

Work will be designed and specified in accordance with applicable laws and regulations of the Federal Government and the State of California and applicable local codes and ordinances. Except where noted otherwise, the latest issue of codes and standards, including addenda, in effect at the start of the project will be used. The codes and standards, including addenda, in effect at the time of purchase will be used for material and equipment procurement.

A summary of the codes and the standards to be used in design and construction follows:

- Seismic standards and criteria will follow the California Building Code (CBC).
- Specifications for materials will follow the standard specifications of the American Society for Testing and Materials (ASTM) and the American National Standards Institute (ANSI), unless noted otherwise.
- Field and laboratory testing procedures for materials will follow ASTM standards.
- Structural concrete and reinforcing steel will be designed and placed in accordance with the codes, guides, and standards of the American Concrete Institute (ACI) and the Concrete Reinforcing Steel Institute (CRSI).

- Structural steel will be designed, fabricated, and erected in accordance with the American Institute of Steel Construction (AISC) Steel Construction Manual, AISC 325.
- Steel components for metal wall panels and roof decking will conform to the American Iron and Steel Institute (AISI) Specification for the Design of Cold-Formed Steel Structural Members.
- Welding procedures and qualifications for welders will follow the recommended practices and codes of the American Welding Society (AWS).
- Metal surfaces for coating systems will be prepared following the specifications and standard practices of the Steel Structures Painting Council (SSPC) and the specific instructions of the coatings manufacturer.
- Masonry materials will be designed and erected in accordance with the ACI Building Code Requirements for Masonry Structures.
- Roof covering design will comply with the requirements of the National Fire Protection Association (NFPA) and Factory Mutual (FM).
- Design and construction will conform to federal and California Occupational Safety and Health Administration (OSHA and CAL/OSHA) requirements.

Other recognized standards will be used where required to serve as guidelines for design, fabrication, and construction. When no other code or standard governs, the CBC, 2007 Edition will govern.

2.2 Government Rules and Regulations

The following laws, ordinances, codes, and standards are applicable to structural design and construction. In cases where conflicts between cited codes (or standards) exist, the requirements of the more stringent code will govern.

The State of California has advised that they will incorporate the International Building Code (IBC) 2006 Edition into the California Building Code (CBC) on January 1, 2008. Where sections in the CBC have been quoted throughout this document as reference, these sections are based on the 1998 edition of the CBC. However, the latest edition of CBC in force at the start of the project will apply to the engineering design.

2.2.1 Federal

- Title 29, Code of Federal Regulations (CFR), Part 1910, Occupational Safety and Health Standards.
- Title 29, CFR, Part 1926, National Safety and Health Regulations for Construction.
- Walsh-Healy Public Contracts Act (Public Law [PL] 50-204.10).

2.2.2 State

- Business and Professions Code Section 6704, et seq.; Sections 6730 and 6736. Requires state registration to practice as a Civil Engineer or Structural Engineer in California.

- Labor Code Section 6500, et seq. Requires a permit for construction of trenches or excavations 5 feet or deeper into which personnel will descend. This also applies to construction or demolition of any building, structure, false work, or scaffolding which is more than three stories high or equivalent.
- Title 24, California Code of Regulations (CCR) Section 2-111, et seq.; Section 3-100, et seq.; Section 4-106, et seq.; Section 5-1021, et seq.; Section 6-T8-769, et seq.; Section 6-T8-3233, et seq.; Section 6-T8-3270, et seq., Section 6-T8-5138, et seq.; Section 6-T8-5465, et seq.; Section 6-T8-5531, et seq.; and Section 6-T8-5545, et seq. Adopts current edition of CBC as minimum legal building standards.
- Title 8 CCR Section 450, et seq. and Section 750, et seq. Adapts American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASMEB and PVC) and other requirements for unfired and fired boilers.
- Title 8, CCR Section 1500, et seq.; Section 2300, et seq.; and Section 3200, et seq. Describes general construction safety orders, industrial safety orders, and work safety requirements and procedures.
- Regulations of the following state agencies as applicable:
  - Department of Labor and Industry Regulations.
  - Bureau of Fire Protection.
  - Department of Public Health.
  - Water and Power Resources.

2.2.3 Local

- California Building Code.

2.3 Industry Codes and Standards

2.3.1 American Concrete Institute (ACI)

- ACI 117—Standard Specification for Tolerances for Concrete Construction and Materials.
- ACI 211.1—Standard Practice for Selecting Proportions of Normal, Heavyweight, and Mass Concrete.
- ACI 301—Specifications for Structural Concrete for Buildings.
- ACI 302.1R—Guide for Concrete Floor and Slab Construction.
- ACI 304R—Guide for Measuring, Mixing, Transporting, and Placing Concrete.
- ACI 305R—Hot Weather Concreting.
- ACI 306R—Cold Weather Concreting.
- ACI 308—Standard Practice for Curing Concrete.
- ACI 309R—Guide for Consolidation of Concrete.

- ACI 311AR—Guide for Concrete Inspection.
- ACI 318—Building Code Requirements for Reinforced Concrete.
- ACI 318.1—Building Code Requirements for Structural Plain Concrete.
- ACI 347R—Guide to Formwork for Concrete.
- ACI 530—Building Code Requirements for Masonry Structures.
- ACI 530.1—Specifications for Masonry Structures.

2.3.2 American Institute of Steel Construction (AISC)

- AISC 303—Code of Standard Practice for Steel Buildings and Bridges.
- AISC 325—Steel Construction Manual.
- AISC 360—Specification for Structural Steel Buildings.
- AISC 341—Seismic Provisions for Structural Steel Buildings

2.3.3 American Iron and Steel Institute (AISI)

- NAS—North American Specification for the Design of Cold-Formed Steel Structural Members.

2.3.4 American Society for Testing and Materials (ASTM)

- ASTM A36—Standard Specification for Carbon Structural Steel.
- ASTM A53—Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
- ASTM A82—Standard Specification for Steel Wire, Plain, for Concrete Reinforcement.
- ASTM A106—Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service.
- ASTM A108—Standard Specification for Steel Bars, Carbon, Cold Finished, Standard Quality.
- ASTM A123—Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
- ASTM A153—Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
- ASTM A185—Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement.
- ASTM A240—Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels.
- ASTM A276—Standard Specification for Stainless and Heat-Resisting Steel Bars and Shapes.

- ASTM A307—Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.
- ASTM A325—Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength.
- ASTM A446—Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Structural (Physical) Quality.
- ASTM A500—Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
- ASTM A501—Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.
- ASTM A569—Standard Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial Quality.
- ASTM A615—Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.
- ASTM A706—Standard Specification for Low-alloy Steel Deformed and Plain Bars for Concrete Reinforcement.
- ASTM A992 Standard Specification for Structural Shapes
- ASTM B695—Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel.
- ASTM C31—Standard Practice for Making and Curing Concrete Test Specimens in the Field.
- ASTM C33—Standard Specification for Concrete Aggregates.
- ASTM C39—Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
- ASTM C90—Standard Specification for Load-Bearing Concrete Masonry Units.
- ASTM C94—Standard Specification for Ready-Mixed Concrete.
- ASTM C109—Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2 in. or 50 mm Cube Specimens).
- ASTM C129—Standard Specification for Non-Load-Bearing Concrete Masonry Units.
- ASTM C136—Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
- ASTM C138—Standard Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete.
- ASTM C143—Standard Test Method for Slump of Hydraulic Cement Concrete.
- ASTM C150—Standard Specification for Portland Cement.

- ASTM C172—Standard Practice for Sampling Freshly Mixed Concrete.
- ASTM C231—Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.
- ASTM C260—Standard Specification for Air-Entraining Admixtures for Concrete.
- ASTM C270—Standard Specification for Mortar for Unit Masonry.
- ASTM C289—Standard Test Method for Potential Reactivity of Aggregates (Chemical Method).
- ASTM C494—Standard Specification for Chemical Admixtures for Concrete.
- ASTM C586—Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (Rock Cylinder Method).
- ASTM C618—Standard Specification for Coal Fly Ash and Raw or Calcinated Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete.
- ASTM C1064—Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete.
- ASTM C1107—Standard Specification for Packaged Dry, Hydraulic Cement Grout (Nonshrink).
- ASTM D1752—Standard Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction.
- ASTM E329—Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction.
- ASTM F1554—Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength.

2.3.5 American Society of Mechanical Engineers (ASME)

- Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels, Division 2 - Alternative Rules.
- ASME/STS-1, Steel Stacks.

2.3.6 American Society of Civil Engineers (ASCE)

- ASCE 7—Minimum Design Loads for Buildings and Other Structures.

2.3.7 American Water Works Association (AWWA)

- AWWA D100—Welded Steel Tanks for Water Storage.

2.3.8 American Welding Society (AWS)

- AWS D1.1—Structural Welding Code - Steel.
- AWS D1.4—Structural Welding Code - Reinforcing Steel.

2.3.9 California Energy Commission

- Recommended Seismic Design Criteria for Non-Nuclear Generating Facilities in California.

2.3.10 Concrete Reinforcing Steel Institute (CRST)

- Manual of Standard Practice.

2.3.11 International Code Council

- CBC—California Building Code.
- IBC—International Building Code.

2.3.12 Metal Building Manufacturers Association (MBMA)

- Low Rise Building Systems Manual.

2.3.13 National Fire Protection Association (NFPA)

- NFPA 22—Standard for Water Tanks for Private Fire Protection.
- NFPA 24—Standard for the Installation of Private Fire Service Mains and Their Appurtenances.
- NFPA 80—Standard for Fire Doors and Fire Windows.
- NFPA 101—Life Safety Code
- NFPA 850—Recommended Practice for Fire Protection for Electric Generating Plants.

2.3.14 Steel Structures Painting Council (SSPC)

- Steel Structures Painting Manual, Volume 2, Systems and Specifications.

2.3.15 Research Council on Structural Connections (RCSC)

- Specification for Structural Joints Using ASTM A325 or A490 Bolts.

3.0 Structural Design Criteria

3.1 Natural Phenomena

The design criteria based on natural phenomena are discussed in this section. The climatological data listed were retrieved from the Local Climatological Data, Annual Summaries for 1998, Stockton, CA. The data cover a period of record from 1937 to 1998. The detail design will be based on the latest available data at the start of the project.

3.1.1 Rainfall

- Maximum 24 Hour: 3.01 inches.
- Maximum Monthly: 8.22 inches.
- Normal Annual: 13.95 inches.

The rainfall design basis may vary for the different systems and system components. Precipitation amounts and intensities to be used with each design basis for various durations and return periods will be obtained from TR-25.

3.1.2 Wind Speed

The maximum recorded 5-second wind speed for 1998 is 54 mph. The maximum recorded 2-minute wind speed is 41 mph. The Annual Summary for Local Climatological Data recently introduced 5-second and 2-minute measurements for wind speed. As a result, the Period of Record (POR) for these measurements is only 9 years.

The design basic wind speed will be 85 miles per hour (3-second gust), as determined from Figure 1609 of the IBC. This design wind speed will be used to determine wind loads for all structures as discussed in Section 3.2.3, Wind Loads.

3.1.3 Temperature

- Maximum: 114° F (1972).
- Minimum: 17° F (1990).
- Normal Dry Bulb: 61.6° F.

3.1.4 Relative Humidity

The relative humidity ranges from 26 to 90 percent.

3.1.5 Seismicity

The seismic hazard for the plant site is defined using S_{DS} = 1.23g, S_{D1} = 0.61g, Site Class D, Occupancy Category III and Importance Factor of 1.25 as determined from IBC 2006.

3.1.6 Snow

The plant site is located in a region with zero ground snow load.

3.2 Design Loads

3.2.1 Dead Loads

Dead loads include the weight of all components forming the permanent parts of structures and all permanent equipment. The dead load of permanent plant equipment will be based on actual equipment weights. For major equipment, structural members and foundations will be specifically located and designed to carry the equipment load into the structural system. For equipment weighing less than the uniform live load, the structural system will be designed for the uniform live load.

The contents of tanks and bins at full operating capacity will be considered as dead loads. The contents of tanks and bins will not be considered effective in resisting uplift due to wind forces, but will be considered effective for seismic forces.

A uniform load of 50 psf will be used to account for piping and cable trays, except in administration building areas, and will be carried to the columns and foundations as dead loads. Uniform piping and cable tray loads will not be considered effective in resisting uplift due to wind forces, but will be considered effective for seismic forces. Additional piping

loads will be considered in the design of areas with heavy piping concentrations. After critical and/or heavy piping hanger loads and locations are established, the supporting members will be reviewed for structural adequacy.

For piperacks, the weight of piping and cable trays will be treated as live load.

3.2.2 Live Loads

- Live loads are the loads superimposed by the use and occupancy of the building or structure. They do not include wind loads, snow loads, or seismic loads.

Uniformly distributed live loads are specified to provide for movable and transitory loads, such as the weight of people, office furniture and partitions, portable equipment and tools, and other nonpermanent materials. These uniform live loads will not be applied to floor areas permanently occupied by equipment, with no access beneath. Uniform live loads for equipment lay-down areas will be based on the actual weight and size of the equipment and parts that may be temporarily placed on floors during dismantling, maintenance, installation, or removal.

The design live loads will be as follows:

- **Ground Floor (Grade Slab)—**A uniform load of 250 psf, nonpermanent equipment weights, storage weights, or lay-down weights, whichever is greater, will be used.
- **Grating Floors, Platforms, Walkways, and Stairs—**A uniform live load of 100 psf will be used. In addition, a concentrated load of 2 kips will be applied concurrently to the supporting beams to maximize stresses in the members, but the reactions from the concentrated load will not be carried to columns. Maximum deflection of the grating will be limited to 1/200 of the span.
- **Elevated Concrete Slabs—**A uniform load of 100 psf, nonpermanent equipment weights, storage weights, or lay-down weights, whichever is greater, will be used.

Elevated concrete slabs will be designed to support either the prescribed live load or a single concentrated load of 2 kips, whichever produces the greater stresses. The concentrated load will be treated as a uniformly distributed load acting over an area of 2.5 square feet and will be located to produce the maximum stress conditions in the slab.

Metal decking for concrete slabs will be designed for a load during construction equal to the weight of concrete plus 50 psf (no increase in allowable stress).

- **Roof—**Roof areas will be designed for a minimum live load of 20 psf. Ponding loading effect due to roof deck and framing deflections will be investigated in accordance with Appendix 2 of AISC 360, Specification for Structural Steel Buildings.
- **Piperacks—**A minimum uniform load of 100 psf will be used for each level of the piperacks, except that, where piping and cable tray loads exceed 100 psf, the actual loads will be used. In addition, a concentrated load of 5 kips will be applied concurrently to the supporting beams to maximum stresses in the members, but the reactions from the concentrated loads will not be carried to columns.

- **Truck Loads—**A surcharge load of 250 psf will be applied to plant structures accessible to truck traffic.

Roads pavements, underground piping, conduits, sumps, and foundations subject to truck traffic will be designed for wheel loadings in accordance with Appendix H1, Section 3.2.2.

- **Thermal Forces—**Thermal forces caused by thermal expansion of equipment and piping under all operating conditions will be considered.
- **Dynamic Loads—**Dynamic loads will be considered and applied in accordance with the manufacturer's criteria/recommendations and industry standards.

3.2.3 Wind Loads

Wind loads for structures and their components will be determined in accordance with the IBC, using a basic wind speed of 85 mph (3-second gust) at 33 feet above grade. Category III and an Importance Factor of 1.15 will be used.

3.2.4 Seismic Loads

Seismic loads will be determined in accordance with the requirements specified in Section 3.4.

3.2.5 Other Loads

Other expected loads required to predict the structural response of structures will be considered where appropriate (i.e., water hammer, test loads, etc.).

3.2.6 Load Combinations

Applicable code-prescribed load combinations will be considered in the design of structures. As a minimum, the following load combinations will be considered:

- Dead load.
- Dead load + live load + operating loads.
- Dead load + live load + operating loads + wind load.
- Dead load + live load + operating loads + seismic load.
- Dead load + construction loads.
- Dead load + live load + emergency loads.
- Dead load + wind load.
- Dead load + seismic load.

Operating loads include all loads associated with normal operation of the equipment (e.g., temperature and pressure loads, piping loads, normal torque loads, impact loads, etc.).

3.2.7 Strength Requirements

Each load combination will not exceed the stress or strength levels permitted by the appropriate code for that combination.

3.2.7.1 Concrete Structures

The required strength (U) of concrete structures will be at least equal to the following:

- U = 1.4 Dead.
- U = 1.2 Dead + 1.6 Live + 1.6 Earth Pressure.
- U = 1.2 Dead + 0.5 Live + 1.6 Wind.
- U = 0.9 Dead + 1.6 Wind + 1.6 Earth Pressure.
- U = 1.2 Dead + 0.5 Live + 1.0 Seismic.
- U = 0.9 Dead + 1.0 Seismic + 1.6 Earth Pressure.

3.2.7.2 Steel Structures

The required strength will be based on elastic design methods, and will use either the Load and Resistance Factor Design (LRFD) or the Allowable Strength Design (ASD) method as defined in AISC 360, Specification for Structural Steel Buildings. The required strength (U) for the LRFD method will be as given above for Concrete Structures. The required strength (S) for the ASD method will be at least equal to the following:

- S = Dead.
- S = Dead + Live.
- S = Dead + Wind.
- S = Dead + 0.7 Seismic.
- S = Dead + 0.75 Live + 0.75 Wind.
- S = Dead + 0.75 Live + 0.525 Seismic.

For load combinations including seismic loading, frame members and connections will conform to the additional requirements of Section 2205 of the IBC.

3.2.8 Factors of Safety

Minimum factors of safety for foundations supporting structures, tanks, and equipment supports will be as follows:

- Overturning—1.50.
- Sliding:
  - 1.10 for seismic load.
  - 1.50 for wind load.
- Buoyancy—1.25.
- Uplift due to wind—1.50.

3.3 Materials

3.3.1 Structural Steel

3.3.1.1 General

Structural steel will conform to ASTM A36, A992, or other materials as required and accepted for use by AISC 360, Specification for Structural Steel Buildings.

High strength bolts for connections will conform to ASTM A325. Bolts other than high strength bolts will conform to ASTM A307, Grade A. Nonheaded anchor bolts will conform

to ASTM F1554. Drilled-in expansion anchors for concrete will be Hilti Kwik Bolts TZ, HSL, HDA, or equivalent.

Structural steel will be detailed and fabricated in accordance with AISC 303, Code of Standard Practice and AISC 360, Specification for Structural Steel Buildings. Structural material will be fabricated and assembled in the shop to the greatest extent possible. Structural members will be welded in accordance with AWS D1.1. Columns will be milled to bear on the baseplate or cap plate. Connections will have a minimum of two bolts.

Exterior structural steel will be either hot-dip galvanized or shop primed and finish painted after installation. Interior structural steel will be shop primed after fabrication. Surface preparation and painting will be in accordance with SSPC standards. Galvanizing will be in accordance with the requirements of ASTM standards.

3.3.1.2 Design and Testing

Steel structures will be designed by either the LRFD or the ASD methods in accordance with the CBC and AISC 360, Specification for Structural Steel Buildings. Connections will be in accordance with AISC 325, Manual of Steel Construction and the RCSC Specification for Structural Joints Using ASTM A325 or A490 Bolts.

Steel structures will be designed as “rigid frames” using fully-restrained (FR) moment connections or as “braced frames”, using single-span beam systems with simple connections, vertical diagonal bracing at main column lines, and horizontal bracing at the roof and major floor levels.

Rigid frames will be generally limited to prefabricated metal buildings. All other framed structures will use braced frame design and construction.

Metal roof and floor decking attached with appropriate welding or fasteners may be considered effective as horizontal diaphragms, provided they are previously qualified by the manufacturer. Grating floors will not be considered as providing horizontal rigidity.

Mill test reports or certificates of conformance certifying that material is in conformance with the applicable ASTM specification will be required. In addition, the fabricator will be required to provide an affidavit stating that steel has been furnished in accordance with the requirements of the drawings and the specifications, including specified minimum yield strength.

3.3.1.3 Handrails, Guardrails, and Toe Plates

Handrails and/or guardrails, except for pre-engineered equipment, will be fabricated from standard weight steel pipe and fittings, either galvanized or painted. Handrails will have toe plates where there is no curb.

3.3.1.4 Steel Grating and Grating Stair Treads

The steel to be used for grating and grating treads will conform to either ASTM A36 or ASTM A569. Grating will be rectangular and consist of welded steel construction. Grating will be hot-dip galvanized after fabrication.

Stair treads will have nonslip abrasive nosing and will have end plates for attaching to stringers. Outdoor grating will have a serrated surface.

The Hilti Grating Disk system, or equivalent, will be used for fastening. Grating will have at least a 1-inch bearing support.

Floor and platform openings necessitated by expansion and movement requirements around piping and equipment will be protected as follows:

- Openings more than 1-1/2 inches wide around penetrating objects will be protected by toe plates.
- Openings more than 8 inches wide around penetrating objects will be protected by toe plates and handrails.

3.3.1.5 Stairs and Ladders

Stairs will be the means of travel from one elevation to another. Vertical ladders, ship ladders, etc., will be installed only where personnel access is infrequent.

Fixed ladders will have safety cages and/or other fall prevention devices as required by the applicable codes and regulations. Stairs will have handrails on both sides.

3.3.2 3Concrete and Reinforcing Steel

3.3.2.1 General

Materials for concrete will comply with ACI 301. Cement will be portland cement meeting the requirements of ASTM C150. Fine aggregates will be clean natural sand. Coarse aggregates will be crushed stone or gravel. Aggregates will conform to the chemical and physical requirements of ASTM C33. Only clean water of potable quality and satisfying the requirements of ASTM C94 will be used.

Admixtures such as plasticizers and retarders may be used to improve workability and control setting time. Concrete will have an entrained air content between 3 and 6 percent by volume. Air-entraining admixtures will meet ASTM C260 requirements. Water reducing admixtures will conform to ASTM C494, Type A. Calcium chloride or admixtures containing calcium chloride will not be used.

Concrete reinforcing will be deformed bars of intermediate grade billet steel conforming to ASTM A615, Grade 60, or welded wire fabric conforming to ASTM A185.

3.3.2.2 Mix Design.

Concrete mix designs will be proportioned and furnished in accordance with ACI 211.1, ASTM C94, and CBC Section 1905. Proportions for the concrete mixture will be selected to meet the strength requirements specified in design documents. Generally, a minimum concrete compressive strength of 4,000 psi at 28 days will be required for structural concrete. Final concrete mix designs will be established based on historical strength performance data or trial mixtures meeting the requirements of Section 1905 of the CBC.

3.3.2.3 Testing and Material Certification

Certified mill test reports on chemical and physical properties confirming compliance with ASTM C150 will be required for each shipment of cement used.

Certificates of Conformance will be obtained from the supplier, certifying that aggregates used comply with the chemical and physical requirements of ASTM C33. Gradation

analyses of fine and coarse aggregates, performed in accordance with ASTM C136, will also be provided.

The manufacturer will certify that the admixture provided conforms to the specified ASTM standard and that it contains no chlorides except those that may be contained in the water used in manufacturing the admixture.

The slump, air content, and temperature of the concrete at the point of discharge from the conveying vehicle will be tested in accordance with specified minimum testing frequencies. Concrete strength will be evaluated in accordance with ASTM C94 and CBC Section 1905.

Mill test reports certifying that reinforcing steel is in accordance with ASTM and project specifications will be required.

3.3.2.4 Design

Reinforced concrete structures will be designed by the Strength Design Method, in accordance with the CBC and ACI 318, Building Code Requirements for Reinforced Concrete.

3.4 Seismic Design Criteria

This section provides the general criteria and procedures to be used for the seismic design of buildings, structures, and structural components.

3.4.1 Seismic Performance Objectives

The seismic performance objectives for this facility are as follows:

- Resist minor levels of earthquake ground motion without damage.
- Resist moderate levels of earthquake ground motion without structural damage, but with some nonstructural damage.
- Resist major levels of earthquake ground motion without collapse, but with some structural as well as nonstructural damage.

To achieve these objectives and to meet the requirements of the California Energy Commission (CEC) and local codes, the facility will be designed in accordance with the CBC.

3.4.2 General Criteria

The seismic hazard for the plant site is defined by S_{DS} = 1.23g, S_{D1} = 0.61g and Site Class D according to IBC 2006. For seismic load calculations, the Importance Factor for Category III structures (power plants) is 1.25 based on the 2006 IBC.

Buildings and structures will be designed using either the equivalent lateral force procedure or the modal response spectrum analysis procedure, as defined in the applicable CBC Section.

Buildings and structures requiring ground motion representation will be designed utilizing the elastic design response spectrum in accordance with the applicable CBC Section.

Lateral forces on elements of structures and nonstructural components supported by structures will be determined in accordance with applicable CBC Section.

Water storage tanks will meet the seismic design requirements of AWWA D100, Appendix H1.

3.5 Architecture

3.5.1 General

Architectural work will be in accordance with the applicable laws, ordinances, codes and industry standards, design criteria, guidelines, general requirements, and material selection specified in this section.

The plant will be laid out to accommodate the spaces required for plant equipment and operations. Aisles and clearances will provide access for operation, minor maintenance, and equipment removal. Personnel walkways to equipment (for routine maintenance only), doors, stairs, and other access points will be provided. Plant security and life safety features will also be considered in the plant layout.

3.5.2 Criteria

These criteria are intended to govern the architectural design of structures and facilities.

Safety, construction, fire protection and fire walls, and requirements for the physically handicapped will be in accordance with the requirements of the applicable local, state, and national codes and standards. Requirements of the Americans with Disabilities Act will also be included in the design where applicable.

Plant buildings will be single story pre-engineered buildings with insulated siding. For sloping roofs, roofing will be standing seam metal with insulation and a vapor barrier; for flat roofs, roofing will be single-ply membrane over metal decking with insulation. The Water Treatment Building will house the water treatment equipment, electrical equipment and a chemical laboratory. The equipment areas, electrical rooms, and HVAC equipment spaces will have exposed structure. The laboratory area will have a suspended acoustical ceiling.

Reinforced concrete grade slabs will be treated with a sealer and/or floor hardener, as applicable, to accommodate maintenance or laydown. Interior wall partitions will be concrete block masonry, concrete, or gypsum wallboard on metal studs. Stairs will be concrete, galvanized grating, or checkered plate. Floor drains will be provided as necessary.

3.5.3 Materials

Asbestos- and lead-containing materials will not be used in the facility.

3.5.3.1 Concrete Masonry

Concrete masonry unit (CMU) partitions will generally be used in traffic and spillage areas, in toilets and locker rooms, in the battery and electrical rooms, and as fire boundaries where required by code.

CMU will be both hollow, normal weight, nonload-bearing Type I conforming to ASTM C129, and load-bearing Grade N, Type I conforming to ASTM C90. Mortar will conform to ASTM C270, Type M. CMU will be reinforced as required.

Masonry structures will be designed and constructed in accordance with ACI 530, Buildng Code Requirements for Masonry Structures; ACI 530.1, Specifications for Masonry Structures; and Chapter 21 of the CBC.

3.5.3.2 Preformed Metal Siding

Exterior siding will be either an insulated or an uninsulated field assembled system. Exterior face panels will be 24 gauge minimum; interior face panels will be 22 gauge minimum. Panels will be fabricated from galvanized sheet steel.

The wall system will be designed to withstand the specified wind loading with practical and economical support girt spacing.

Wall insulation will be noncombustible glass fiber to produce a maximum U-factor of 0.08 Btu/h/ft/F.

3.5.3.3 Metal Studwall Partitions

Except when CMU partitions are required, ceiling height interior partitions will generally be of metal stud and painted gypsum board construction.

3.5.3.4 Roofing

Roofing will be either single-ply membrane over rigid insulation board, mechanically fastened to the metal roof deck, or standing seam metal with insulation and vapor barrier. The completed roofing system will conform to UL requirements for Class A roofs and to Factory Mutual wind uplift Class 90. The completed roof will have an overall maximum U-factor of 0.05 Btu/h/ft/F.

3.5.3.5 Metal Roll-Up Doors

Roll-up doors will have insulated door curtains constructed of interlocking roll-formed galvanized steel slats to withstand the specified wind pressure. Doors will be manually operated.

3.5.3.6 Hollow Metal Doors, Frames, and Hardware

Personnel doors will be flush hollow metal on pressed steel door frames, with hinges, locksets, closers, weatherstripping, and accessory hardware. Fire doors and frames will conform to NFPA 80 for the class of door furnished.

3.5.3.7 Louvers

Louvers will be operable, extruded aluminum section alloy, with stainless steel fastenings and removable aluminum bird screen. Blades will be stormproof. Louver free area will be a minimum of 50 percent of louver face area. Louvers will be designed for manual or gravity operation.

3.5.3.8 Floor Finish

Floor finishes will generally be concrete with curing and sealing protection.

All chemical areas will generally receive special coatings.

3.5.4 Painting

Generally, exposed wall surface, structures, and structural components will be primer painted or otherwise treated to protect them from corrosion in accordance with the applicable codes, industry standards, and manufacturer's recommendations.

3.5.4.1 Structural and Miscellaneous Steel

Structural and miscellaneous steel will receive shop applied inorganic zinc primer. Field touchup will be performed after erection. Structural steel requiring fireproofing will either receive no painting or a primer compatible with the selected fireproofing material.

3.5.4.2 Masonry Walls and Concrete Walls and Floors

Concrete floors in areas not exposed to chemical contaminants will not be coated. Indoor masonry walls in areas requiring paint but not exposed to chemical contaminants will be painted with one coat of acrylic filler and a compatible finish coat.

3.5.4.3 Gypsum Wallboard

Exposed surfaces will receive one coat each of sealer and compatible acrylic finish.

4.0 Structural Design Methodology

This section describes the structural aspects of the design of the proposed equipment to convert the existing Simple Cycle facility to a Combined Cycle facility. Each major structural component of the plant equipment to be added is addressed by defining the design criteria and analytical techniques that will be employed.

4.1 Structures

4.1.1 Steam Turbine/Generator Foundation

The steam turbine/generator turbine foundation will be designed to support the turbine and generator components.

Each foundation will be designed to resist the loadings furnished by the manufacturer plus loadings from natural phenomena and structural framing, if applicable, and will be constructed of reinforced concrete.

4.1.1.1 Foundation Loads

Equipment foundation loads will be furnished by the steam turbine/generator manufacturer and will be combined with the other loads imposed on the foundation. Typical loading data supplied by the manufacturer include the following. The steam turbine/generator foundation will be designed for these loads:

- Dead loads.
- Live loads.
- Wind loads.
- Seismic loads.
- Normal torque loads.

- Normal machine unbalance loads.
- Emergency loads, such as turbine accident or generator short circuit.
- Thermal loads due to thermal expansion or contraction of the machines, connected piping, and turbine pedestal components.
- Shrinkage and creep loads.

4.1.1.2 Induced Forces

The steam turbine/generator and associated equipment will be securely anchored to the foundation using cast-in-place steel anchor bolts designed to resist the equipment forces and seismic or wind loads.

4.1.1.3 Structural System

The steam turbine/generator foundation system will consist of a reinforced concrete mat bearing directly on undisturbed soil or compacted fill.

4.1.1.4 Structural Criteria

Each foundation will be designed and constructed as a monolithic reinforced concrete structure using the criteria from Section 3.0 and Appendix H1, Section 3.1. The foundation design will address the following considerations:

- Allowable soil pressures.
- Allowable settlements.
- Equipment, structure, and environmental loads.
- Factors of safety against overturning and sliding.
- Equipment performance criteria.
- Natural frequencies and dynamic effects of rotating equipment.
- Access and maintenance.

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a minimum safety factor of 3 against bearing failure. Total and differential settlements will be limited to the values specified in Appendix H1, Section 3.1.2.

Environmental loadings will be determined in accordance with Sections 3.1 and 3.2. Foundation seismic loading will be calculated as specified in Section 3.4. Seismic forces will be applied at the center of gravity of the equipment.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.1.1.5 Analytical Techniques

Steam Turbine/Generator Foundation

The mat foundation for the steam turbine/generator will be designed using static analysis techniques. If adequate rigidity is provided, the mat will be analyzed as a rigid mat foundation to determine the resulting soil pressures and internal forces and moments. The foundation will be analyzed assuming a linear soil pressure distribution.

If its rigidity is in question, the foundation mat will be considered as a flexible system and modeled as a plate structure using 3-D plate bending elements. The interaction between the mat and supporting soil will be modeled using a system of vertical and horizontal springs attached to a fixed boundary. A computer analysis will be performed using finite element techniques.

The foundation will be checked for dynamic response to the operating turbine. A dynamic analysis will typically be performed by considering the mat foundation as rigid and using a lumped mass model. The lumped mass model will include soil springs and dashpots to account for soil and structure interaction. An analysis will be performed to determine the natural frequencies of the foundation using the lumped mass model. When the rigidity of the mat foundation is in question, the mat will be considered flexible and will be modeled by plate elements, and a dynamic analysis will be performed using finite element computer analysis.

To avoid resonance during machine operation, the resonant frequency of the foundation will typically be less than 80 percent or greater than 120 percent of the machine operating speed.

4.1.2 Heat Recovery Steam Generator (HRSG) Foundations

The HRSG foundations will be designed to support the HRSG components.

Each foundation will be designed to resist the loadings furnished by the manufacturer plus loadings from natural phenomena and structural framing, if applicable, and will be constructed of reinforced concrete.

4.1.2.1 Foundation Loads

Equipment foundation loads will be furnished by the HRSG manufacturer and will be combined with the other loads imposed on the foundation. Typical loading data supplied by the manufacturer include the following. The HRSG foundations will be designed for these loads:

- Dead loads.
- Live loads.
- Wind loads.
- Seismic loads.
- Normal torque loads.
- Thermal loads due to thermal expansion or contraction of the equipment and connected piping.
- Shrinkage and creep loads.

4.1.2.2 Induced Forces

The HRSG and associated equipment will be securely anchored to the foundation using cast-in-place steel anchor bolts designed to resist the equipment forces and seismic or wind loads.

4.1.2.3 Structural System

The HRSG foundation system will consist of a reinforced concrete mat bearing directly on undisturbed soil or compacted fill.

4.1.2.4 Structural Criteria

Each foundation will be designed and constructed as a monolithic reinforced concrete structure using the criteria from Section 3.0 and Appendix H1, Section 3.1. The foundation design will address the following considerations:

- Allowable soil pressures.
- Allowable settlements.
- Equipment, structure, and environmental loads.
- Factors of safety against overturning and sliding.
- Equipment performance criteria.
- Natural frequencies and dynamic effects of rotating equipment.
- Access and maintenance.

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a minimum safety factor of 3 against bearing failure. Total and differential settlements will be limited to the values specified in Appendix H1, Section 3.1.2.

Environmental loadings will be determined in accordance with Sections 3.1 and 3.2. Foundation seismic loading will be calculated as specified in Section 3.4. Seismic forces will be applied at the center of gravity of the equipment.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.1.2.5 Analytical Techniques

HRSG Foundation

The mat foundation for the HRSG will be designed using static analysis techniques. If adequate rigidity is provided, the mat will be analyzed as a rigid mat foundation to determine the resulting soil pressures and internal forces and moments. The foundation will be analyzed assuming a linear soil pressure distribution.

If its rigidity is in question, the foundation mat will be considered as a flexible system and modeled as a plate structure using 3-D plate bending elements. The interaction between the mat and supporting soil will be modeled using a system of vertical and horizontal springs attached to a fixed boundary. A computer analysis will be performed using finite element techniques.

4.1.3 Stacks and Foundations

Each stack will be carbon steel with a separate reinforced concrete mat foundation bearing directly on undisturbed soil or compacted fill or monolithic with the HRSG foundation.

4.1.3.1 Foundation Loads

Foundation loads will be determined using project-specific design criteria. The design will include the following loads:

- Dead load.
- Live loads.
- Wind loads.
- Seismic loads.
- Temperature and pressure loads.

4.1.3.2 Induced Forces

The stack will be securely anchored to its foundation using cast-in-place steel anchor bolts designed to resist the stack-induced forces.

4.1.3.3 Structural System

The steel stack will consist of a cylindrical steel shell that resists lateral loading as a fixed-base, cantilevered structure. The stack foundation system will consist of a reinforced concrete mat bearing directly on undisturbed soil or compacted fill.

4.1.3.4 Structural Criteria

The predominant forces acting on the stack will result from wind or seismic loading. The stack will be designed as indicated in this section.

The steel stack and supports will be capable of enduring specified normal and abnormal design operating conditions in combination with wind or seismic loads for the design life of the facility. The design will be in accordance with the design methods of ASME STS-1, Steel Stacks, and AISC 325, Steel Construction Manual.

Design values for yield strength and modulus of elasticity of the stack material will depend on the composition of the material and the maximum temperature of the metal at design operating conditions and will be as prescribed by the ASME Pressure Vessel Code, Section VIII, Division 2, Part AM.

Wind loads will be determined from the CBC, using Exposure Category C. Consideration will be given to along-wind and across-wind responses, ovalling, and interference effects. Seismic loads will be determined in accordance with CBC for Nonbuilding Structures.

The allowable longitudinal, circumferential, and shear stresses for the design of the stack shell will be determined in accordance with ASME STS-1.

The minimum shell thickness will be 1/4 inch plus 1/16 inch corrosion allowance. The corrosion allowance will be considered in the generation of seismic loads but not in the resistance to seismic or wind loads. Allowable stresses for stiffeners, platform members, and other miscellaneous steel components will be in accordance with AISC 360, Specification for Structural Steel Buildings. Allowable stresses for the shell will not be increased for wind or seismic loadings.

Each foundation will be designed and constructed as a monolithic reinforced concrete structure using the criteria from Section 3.0 and Appendix H1, Section 3.1. The foundation design will address the following considerations:

- Allowable soil pressures.
- Allowable settlements.
- Structure and environmental loads.
- Factors of safety against overturning and sliding.

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a minimum safety factor of 3 against bearing failure. Total and differential settlements will be limited to the values specified in Appendix H1, Section 3.1.2.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.1.3.5 Analytical Techniques

Stack moments, shears, and axial forces will be calculated using static analysis procedures on a cantilevered member. Longitudinal stresses resulting from axial loads and flexure will be combined and compared to a single allowable stress.

Circumferential stresses will also be compared to a single allowable value. Interaction between longitudinal and circumferential stresses will be considered.

The stack foundation will typically be designed using static analysis techniques assuming a rigid mat.

4.1.4 Air Cooled Condenser (ACC) Foundations

The ACC foundations will be designed to support the ACC components.

Each foundation will be designed to resist the loadings furnished by the manufacturer plus loadings from natural phenomena and structural framing and will be constructed of reinforced concrete.

4.1.4.1 Foundation Loads

Equipment foundation loads will be furnished by the ACC manufacturer and will be combined with the other loads imposed on the foundation. Typical loading data supplied by the manufacturer include the following. The ACC foundations will be designed for these loads:

- Dead loads.
- Live loads.
- Wind loads.
- Seismic loads.
- Normal torque loads.

- Thermal loads due to thermal expansion or contraction of the equipment and connected piping.
- Shrinkage and creep loads.

4.1.4.2 Induced Forces

The ACC and associated equipment will be securely anchored to the foundation using cast-in-place steel anchor bolts designed to resist the equipment forces and seismic or wind loads.

4.1.4.3 Structural System

The ACC foundation system will consist of reinforced concrete mats and grade beams bearing directly on undisturbed soil or compacted fill.

4.1.4.4 Structural Criteria

The foundation mats and grade beams will be designed and constructed as a monolithic reinforced concrete structure using the criteria from Section 3.0 and Appendix H1, Section 3.1. The foundation design will address the following considerations:

- Allowable soil pressures.
- Allowable settlements.
- Equipment, structure, and environmental loads.
- Factors of safety against overturning and sliding.
- Equipment performance criteria.
- Natural frequencies and dynamic effects of rotating equipment.
- Access and maintenance.

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a minimum safety factor of 3 against bearing failure. Total and differential settlements will be limited to the values specified in Appendix H1, Section 3.1.2.

Environmental loadings will be determined in accordance with Sections 3.1 and 3.2. Foundation seismic loading will be calculated as specified in Section 3.4. Seismic forces will be applied at the center of gravity of the equipment.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.1.4.5 Analytical Techniques

ACC Foundation

The mat and grade beam foundation for the ACC will be designed using static analysis techniques. If adequate rigidity is provided, the foundation will be analyzed as a rigid mat foundation to determine the resulting soil pressures and internal forces and moments. The foundation will be analyzed assuming a linear soil pressure distribution.

If its rigidity is in question, the foundation will be considered as a flexible system and modeled as a plate structure using 3-D plate bending elements. The interaction between the foundation and supporting soil will be modeled using a system of vertical and horizontal

springs attached to a fixed boundary. A computer analysis will be performed using finite element techniques.

4.1.5 Pipe Rack and Steam Turbine Maintenance Area Structures

The Pipe Rack will be designed to support the pipe and electrical interfaces between then HRSG's and the Steam Turbine/Generator. The Steam Turbine/Generator Maintenance area will be designed to provide area for lay down of parts and personnel access to the equipment during overhaul and maintenance operations.

The Pipe Rack and Steam Turbine/Generator Maintenance Structure foundations will be designed to support the loads from the structures.

Each foundation will be designed to resist the loadings from the equipment and components being supported plus loadings from natural phenomena and structural framing and will be constructed of reinforced concrete.

4.1.5.1 Foundation Loads

The structure foundation loads will be determined during the plant design phase and will be combined with the other loads imposed on the foundation. Typical loading data include the following. The structure foundations will be designed for these loads:

- Dead loads.
- Live loads.
- Wind loads.
- Seismic loads.
- Normal torque loads.
- Thermal loads due to thermal expansion or contraction of the equipment and connected piping.
- Shrinkage and creep loads.

4.1.5.2 Induced Forces

The pipe rack and steam turbine/generator maintenance structures and associated equipment will be securely anchored to the foundation using cast-in-place steel anchor bolts designed to resist the equipment forces and seismic or wind loads.

4.1.5.3 Structural System

The Pipe Rack and Steam Turbine/Generator Maintenance Structures will be designed as AISC Type 1 rigid frames or as Type 2 simple braced frames. For the purpose of resisting seismic lateral loads, the structures will be classified as regular structures with a concentric braced frame, an ordinary moment-resisting frame, or a special moment-resisting frame, in accordance with the definitions of the CBC Chapters 16 to 22.

The structure foundation systems will consist of reinforced concrete mats and grade beams bearing directly on undisturbed soil or compacted fill.

4.1.5.4 Structural Criteria

Pipe Rack and Steam Turbine/Generator Maintenance Structure steel frames will be designed and constructed using the materials and criteria set forth in Section 3.0. Environmental loading will be determined in accordance with Sections 3.1 and 3.2. Seismic loading for the structures will be calculated using equivalent static lateral forces or dynamic lateral forces applied to the structure in accordance with the procedures of CBC.

Structure foundations will be designed and constructed using reinforced concrete according to the criteria set forth in Section 3.0 and Appendix H1, Section 3.1. The foundation design will address the following considerations:

- Allowable soil pressures.
- Allowable settlements.
- Equipment, structure, and environmental loads.
- Factors of safety against overturning and sliding.
- Equipment performance criteria.
- Access and maintenance.

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a minimum safety factor of 3 against bearing failure. Total and differential settlements will be limited to the values specified in Appendix H1, Section 3.1.2.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.1.5.5 Analytical Techniques

Pipe Rack and Steam Turbine/Generator Maintenance Structure Foundations

The mat and grade beam foundations for the structures will be designed using static analysis techniques. If adequate rigidity is provided, the foundations will be analyzed as rigid mat foundations to determine the resulting soil pressures and internal forces and moments. The foundations will be analyzed assuming a linear soil pressure distribution.

If the rigidity is in question, the foundations will be considered as flexible systems and modeled as a plate structures using 3-D plate bending elements. The interaction between the foundation and supporting soil will be modeled using a system of vertical and horizontal springs attached to a fixed boundary. A computer analysis will be performed using finite element techniques.

4.1.6 Buildings and Enclosures

The various plant buildings and enclosures will provide support, protection, and access to the systems contained within their boundaries. Generally, each building and enclosure will be one story and pre-engineered.

4.1.6.1 Foundation Loads

Foundation loads will be determined from the analysis and design of the superstructure and from the support of the equipment contained within the structure. The following loads will be considered:

- Dead loads.
- Live loads.
- Equipment and piping loads.
- Wind loads.
- Seismic loads.

4.1.6.2 Induced Forces

Each building and enclosure will be securely anchored to its foundation using cast-in-place steel anchor bolts designed to resist any induced forces.

4.1.6.3 Structural System

Buildings and enclosures will be designed as rigid frames or as braced frames. For the purpose of resisting seismic lateral loads, the structures will be classified as regular structures with a concentric braced frame, an ordinary moment-resisting frame, or a special moment-resisting frame, in accordance with the definitions of the CBC Chapters 16 to 22.

The foundation systems for buildings and enclosures will consist of individual spread footings to resist the column loads with an isolated slab-on-grade floor system.

4.1.6.4 Structural Criteria

Building and enclosure steel frames will be designed and constructed using the materials and criteria set forth in Section 3.0.

Environmental loading will be determined in accordance with Sections 3.1 and 3.2. Seismic loading for the buildings and enclosures will be calculated using equivalent lateral forces applied to the structure in accordance with the procedures of the CBC.

Building and enclosure foundations will be designed and constructed using reinforced concrete according to the criteria set forth in Section 3.0 and Appendix H1, Section 3.1. The foundation design will address the following considerations:

- Allowable soil pressures.
- Allowable settlements.
- Equipment, structure, and environmental loads.
- Factors of safety against overturning and sliding.
- Equipment performance criteria.
- Access and maintenance.

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a minimum safety factor of 3 against bearing failure. Total and differential settlements will be limited to the values specified in Appendix H1, Section 3.1.2.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.1.6.5 Analytical Techniques

Building and enclosure foundations will be designed as simple spread footings or mat foundations, using static analysis techniques. The foundations will be analyzed assuming a linear soil pressure distribution.

4.2 Tanks

4.2.1 Field-Erected Storage Tanks

Field-erected storage tanks will typically be vertical, cylindrical shells of stainless steel or carbon steel construction with a protective interior coating. Tank roofs will be either self-supported domes or cones. Tank bottoms will be ground-supported, flat-bottomed, with a slope of 1 percent. Tanks will have ladders, landing platforms, and handrails to provide access to working areas. Vents, manholes, overflow piping, and grounding lugs will be provided as necessary.

4.2.1.1 Foundation Loads

Foundation loads will be determined using project-specific design criteria. Tank and foundation design will include the following loads:

- Dead loads (including contained fluid load).
- Live loads.
- Wind loads.
- Seismic loads (including hydrodynamic loads).

4.2.1.2 Induced Forces

Storage tanks will be securely anchored to their foundations using cast-in-place steel anchor bolts designed to resist tank-induced forces.

4.2.1.3 Structural System

Each tank will be a cylindrical steel shell that resists lateral loading through shear in the tank wall. Anchor bolts connecting the tank wall to the foundation will resist overturning.

The tank foundation system will typically consist of a reinforced concrete ringwall or mat foundation. The interior of the ring will consist of compacted backfill with a layer of compacted sand to serve as a bearing surface for the tank bottom. If soil conditions could result in excessive settlements or soil overstress, a complete concrete mat may be required.

4.2.1.4 Structural Criteria

Tank structures will be designed and constructed using the criteria established in AWWA D100 or NFPA 22, as applicable.

Foundations will be designed and constructed as reinforced concrete structures using the criteria from Section 3.0 and Appendix H1, Section 3.1. Foundation design will address the following considerations:

- Allowable soil pressures.
- Allowable settlements.
- Fluid, structure, and environmental loads.
- Factors of safety against overturning and sliding.

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a minimum safety factor of 3 against bearing failure. Total and differential settlements will be limited to the values specified in Appendix H1, Section 3.1.2.

Environmental loadings will be determined in accordance with Sections 3.1 and 3.2. Seismic loads will be determined in accordance with Section 3.4 and AWWA D100, Section 13.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7 and in Section 3 of AWWA D100. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

Tank foundation design will include the moment resulting from lateral displacement (hydrodynamics) of the tank contents in accordance with AWWA D100, Section 13.3.3.2.

4.2.1.5 Analytical Techniques

Tank foundations will typically be designed as circular ringwalls using static analysis techniques. Each ringwall will be proportioned to resist the design load of the tank and the maximum overturning moment due to wind or seismic loading. The ringwall will also be proportioned to resist maximum anchor bolt uplift force. Circumferential reinforcing steel will be provided in the ringwall to develop the hoop stress produced by the lateral soil pressure within the ringwall.

Tank structures will be designed and proportioned so that during the application of any load, or combination of loads, the allowable stresses stipulated in AWWA D100 are not exceeded.

4.2.2 Shop Fabricated Storage Tanks

Shop fabricated storage tanks will be either vertical or horizontal, cylindrical, carbon steel shells. The tanks will have ladders, landing platforms, and handrails, to provide access to working areas. Each tank will have nozzles for fill connection, fill drain, overflow, vent connections, manholes, and grounding lugs as necessary.

4.2.2.1 Foundation Loads

Foundation loads will be furnished by the tank manufacturer and will be superimposed with loads for the foundation itself.

Typical loadings supplied by the manufacturer include the following:

- Dead loads.
- Live loads.
- Wind loads.
- Seismic loads (including hydrodynamic loads).
- Temperature and pressure loads.

4.2.2.2 Induced Forces

Each tank will be securely anchored to its foundation using cast-in-place steel anchor bolts or concrete expansion anchors designed to resist tank-induced forces.

4.2.2.3 Structural System

Each tank will consist of a cylindrical steel shell, either supported by integral legs or saddle supports, or with a flat bottom bearing directly on the foundation.

Foundations will typically consist of individual pads bearing directly on undisturbed soil or compacted fill. For tanks located in buildings, the pads may be constructed integrally with the grade slab.

4.2.2.4 Structural Criteria

Tanks will be designed by a tank manufacturer in accordance with the relevant ASME code, ANSI code, and ASTM standards.

Foundations will be designed and constructed as monolithic reinforced concrete structures using the criteria from Section 3.0 and Appendix H1, Section 3.1. Foundation design will address the following considerations:

- Allowable soil pressures.
- Allowable settlements.
- Fluid, structure, and environmental loads.
- Factors of safety against overturning and sliding.

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a minimum safety factor of 3 against bearing failure. Total and differential settlements will be limited to the values specified in Appendix H1, Section 3.1.2.

Environmental loadings will be determined in accordance with Sections 3.1 and 3.2. Seismic loading will be calculated using equivalent static lateral forces applied at the center of gravity of the tank or tank component in accordance with the criteria specified in Section 3.4.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.2.2.5 Analytical Techniques

The tank foundations will typically be designed using static analysis techniques assuming a rigid mat. The foundations will be analyzed assuming a linear soil pressure distribution. The mats will be proportioned so that the resultant of the soil pressure coincides as nearly as possible with the resultant of the vertical loading.

The tanks will be designed and analyzed by a tank manufacturer to satisfy the requirements of the relevant ASME code, ANSI code, and ASTM standards.

4.3 Equipment and Equipment Foundations

Plant equipment will be designed in accordance with manufacturers' standards and applicable codes and industry standards. Equipment will be designed to resist project-specific environmental loadings, as applicable.

Foundations will be designed to resist the loadings furnished by the manufacturers and will be constructed of reinforced concrete.

Specific criteria for the combustion turbine foundations are addressed in Section 4.1.1.

4.3.1 Equipment/Foundation Loads

Equipment and foundation loads will be determined by the manufacturers using project-specific design criteria. Typical loadings used for design will include the following:

- Dead loads.
- Live loads.
- Operating loads.
- Wind loads.
- Seismic loads.
- Emergency loads.

Foundation loads furnished by the equipment manufacturers will be superimposed with loads for the foundation itself.

4.3.2 Induced Forces

The equipment will use steel anchor bolts, concrete expansion anchors, welds, and other equipment anchorage devices to resist equipment-induced forces.

4.3.3 Structural System

Foundations will typically consist of individual pads bearing directly on undisturbed soil or compacted fill. For equipment located in buildings, the pads may be constructed integrally with the grade slab.

4.3.4 Structural Criteria

Plant equipment will be designed to resist project-specific criteria in accordance with the manufacturers' standards and applicable codes and industry standards.

Environmental loading will be determined in accordance with Sections 3.1 and 3.2. Seismic loading will be calculated using equivalent static lateral forces applied at the center of gravity of the equipment or component in accordance with the criteria specified in Section 3.4.

Seismic lateral forces on equipment supported by structures will be determined in accordance with applicable CBC Sections. Equipment bases, foundations, support frames, and structural members used to transfer equipment seismic forces to the main lateral load-resisting system will be designed for the same seismic load as the equipment.

Integral support structures provided by manufacturers with their equipment, such as the combustion turbine air inlet support structure, will be designed to resist, at a minimum, the lateral forces specified in CBC Section for Nonbuilding Structures, and the applicable criteria of Section 3.4.

Load combinations will be as indicated in Section 3.2.6. These load combinations are in addition to those normally used in design and those specified in applicable codes and standards.

Equipment foundations will be designed and constructed as monolithic reinforced concrete structures using the criteria from Section 3.0 and Appendix H1, Section 3.1. The foundation design will address the following considerations:

- Allowable soil pressures.
- Allowable settlements.
- Equipment and environmental loads.
- Factors of safety against overturning and sliding.
- Equipment performance criteria.
- Access and maintenance.

Soil pressures will satisfy the allowable bearing pressure criteria that will be developed during project detailed design to provide a minimum safety factor of 3 against bearing failure. Total and differential settlements will be limited to the values specified in Appendix H1, Section 3.1.2.

Load combinations and their respective strength requirements for the foundation design will be as indicated in Sections 3.2.6 and 3.2.7. Factors of safety against overturning and sliding will satisfy the requirements of Section 3.2.8.

4.3.5 Analytical Techniques

Equipment foundations will typically be designed using static analysis techniques assuming a rigid mat. Foundations will be analyzed assuming a linear soil pressure distribution. Mats will be proportioned so that the resultant of the soil pressure coincides as nearly as possible with the resultant of the vertical loading.

Equipment will be designed and analyzed by the manufacturer to satisfy the requirements of the relevant codes and industry standards.

5.0 Hazard Mitigation

The project will be designed to mitigate natural and environmental hazards caused by seismic and meteorological events. This section addresses the structural design criteria used to mitigate these hazards.

5.1 Seismic Hazard Mitigation Criteria

Appendix H1 and this appendix describe the civil and structural design criteria that will be applied to the project.

Project seismic design criteria were selected based on the following considerations:

- Compliance with applicable laws, ordinances, regulations, codes, and life safety.
- Structural behavior and performance.
- Reliability of the plant.
- Financial impacts from seismically induced outages.
- Seismic probability and magnitude.

The project seismic design criteria were developed to incorporate these considerations using a systematic approach to correlate performance criteria with assumed risk level. The following procedure was used to establish the design criteria:

- Seismic hazard for the site defined by S_{DS} = 1.23g, S_{D1} = 0.61g and Site Class D in the IBC 2006 Edition was determined to be appropriate for structural design.
- Appropriate design criteria and analysis methods consistent with the seismic performance criteria were established for each major plant structure, equipment, and component.
- Acceleration levels for various structural frequencies will be based on the applicable CBC Design Response Spectra Shapes Figures.

Specific design features that will be incorporated into the plant to mitigate the identified seismic hazards include the following:

- Appropriate analysis techniques will be employed to calculate structure-specific seismic loads.
- Plant structures, equipment, piping, and other components will be designed to resist the project-specific seismic loads.
- Critical equipment will be positively anchored to its supporting structure.
- Anchorages will be designed to resist project-specific seismic loadings.
- Adequate factors of safety against overturning and sliding due to seismic loads will be provided.
- The design of piping connections to structures, tanks, and equipment will consider differential seismic displacements between components.
- Adjacent structures will be seismically isolated from one another.
- Structural elements will be designed to comply with special detailing requirements intended to provide ductility.
- Connections for steel structures will have a minimum load carrying capability without regard to the calculated load.
- Lateral and vertical displacements of structures and elements of structures will be limited to specified values.
- Appropriate measures will be taken to prevent saturation of foundation soils and eliminate the potential for soil liquefaction.

The foregoing design features are intended to provide the degrees of safety for structures and equipment as follows:

- Resist minor earthquakes without damage. Plant remains operational.

- Resist moderate earthquakes without structural damage but with some nonstructural damage. Plant remains operational or is returned to service following visual inspection and/or minor repairs.

Resist design basis major earthquake without collapse but with structural and nonstructural damage.

5.2 Meteorological and Climatic Hazard Mitigation

Meteorological and climatic data were used to establish the project design basis. Portions of the data and the design bases that pertain to structural engineering are provided in this appendix.

Specific design features which will be incorporated into the plant to mitigate meteorological and climatic hazards include the following:

- Structures and cladding will be designed to resist the wind forces.
- Sensitive structures will be designed for wind-induced vibration excitation.
- Roofs will be sloped and equipped with drains to prevent accumulation of rainfall.
- Site drainage systems will be designed to convey the runoff from a 25 year storm event with a time of concentration of 10 minutes.
- Ground floor levels of structures will be placed above probable flood levels.
- Building drainlines will be installed with backflow prevention devices where necessary.
- The bases of plant equipment will be placed above probable flood levels.
- The plant site will be graded to convey runoff away from structures and equipment.

The foregoing design features will be incorporated in accordance with the applicable codes and standards identified in this appendix.

The degree of safety offered by these features is consistent with the requirements of the applicable codes and standards and the economic benefits these features provide.

APPENDIX 2A.3

Mechanical Engineering Design Criteria

APPENDIX 2A3

Mechanical Engineering Design Criteria

1.0 Introduction

This section covers the design criteria which will be used for all mechanical work related to this project.

2.0 Design Codes and Standards

The design and specification of all work shall be in accordance with the laws and regulations of the federal government and the state of California, and local codes and ordinances. The following laws, ordinances, codes, and standards have been identified as applying to mechanical engineering design and construction. In cases where conflicts between cited codes (or standards) exist, the requirements of the more conservative code will be met.

Federal

- Title 29 Code of Federal Regulations (CFR) Part 1910, Occupational Safety and Health Administration (OSHA).
- Title 40 CFR Part 60, Standards of Performance for New Stationary Sources.
- Title 40 CFR Part 75, Continuous Emission Monitoring.
- Title 40 CFR Subchapter C, Air Programs, Part 50 et seq.
- Title 40 CFR Subchapter D, Water Programs, Part 100 et seq.
- Title 40 CFR Subchapter I, Solid Waste and Hazardous Waste, Part 260 et seq.
- Title 40 CFR Subchapter J, Superfund Emergency Planning and Community Right-to-Know Act, Part 300 et seq.
- Title 40 CFR Subchapter N, Effluent Guidelines and Standards, Part 400 et seq.
- Title 49 CFR Part 192, Transportation of Natural and Other Gas by Pipeline.

State

- California Occupational Safety and Health Administration (CAL-OSHA).
- Title 8 California Code of Regulations (CCR) Chapters 4 through 7, Groups 20 Flammable Liquids, Gases, and Vapors, Chapter 27 Fire Protection.
- Title 14 CCR Natural Resources.
- Title 17 CCR Public Health.

- Title 19 CCR Public Safety.
- Title 20 CCR Public Utilities and Energy.
- Title 22 CCR Social Security Division 4.5 Minimum Standards for Management of Hazardous and Extremely Hazardous Waste.
- Title 23 CCR Waters.
- Title 24 CCR California Building Code, California Mechanical Code, and California Plumbing Code.
- Title 26 CCR Toxics.
- California Business and Professional Code Section 6704 (requires state registration to practice engineering) and Section 6735 (requires engineering documents to be prepared by a registered engineer).
- Regulations of the following state agencies, as applicable:
  - Department of Labor and Industry Regulations
  - Bureau of Fire Protection
  - Department of Public Health
  - Water and Power Resources

Industry Codes and Standards

- ABMA—American Bearing Manufacturers Association:
  - ABMA 9—Load Ratings and Fatigue Life for Ball Bearings.
  - ABMA 11—Load Ratings and Fatigue Life for Roller Bearings.
- ACPI—American Concrete Pipe Association Standards.
- AGMA—American Gear Manufacturers Association Standards.
- AISC—American Institute of Steel Construction Standards.
- AMCA – Air Moving and Conditioning Association.
- API— American Petroleum Institute:
  - API 5L—Specification for Line Pipe.
  - API 599—Steel and Ductile Iron Plug Valves
  - API 608—Metal Ball Valves – Flanged and Butt-Welding Ends
  - API 609—Lug and Wafer-type Butterfly Valves
  - API 610—Centrifugal Pumps for Petroleum, Heavy-Duty Chemical and Gas Industry Services
- ASA—Acoustical Society of America:
  - ASA 47—Sound Level Meters.
  - ASA 53—Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements.
- ASHRAE—American Society of Heating, Refrigerating and Air Conditioning Standards.

- ASTM—American Society for Testing and Materials:
  - ASTM A36/A36M—Specification for Structural Steel.
  - ASTM A53—Standard Specification for Pipe, Steel, Black, and Hot-Dipped, Zinc-Coated Welded and Seamless.
  - ASTM A105/A105M—Standard Specification for Forgings, Carbon Steel, for Piping Components.
  - ASTM A106—Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service.
  - ASTM A126—Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings.
  - ASTM A134—Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over).
  - ASTM A182/A182M—Standard Specification for Forged or Rolled Alloy Steel Pipe Flanges/Forged Fitting and Valves and Parts for High-Temperature Service.
  - ASTM A193/A193M—Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.
  - ASTM A194/A194M—Standard Specifications for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service.
  - ASTM A213/A213M—Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes.
  - ASTM A216/A216M—Standard Specifications for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service.
  - ASTM A217/A217M—Standard Specification for Steel Castings, Martenistic Stainless and Alloy for Pressure Containing Parts, Suitable for High-Temperature Service.
  - ASTM A234/A234M—Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures.
  - ASTM A283/A283M—Specification for Low and Intermediate Tensile Strength Carbon Steel Plates.
  - ASTM A307—Standard Specifications for Carbon Steel Bolts and Studs, 60,000 psi, Tensile Strength.
  - ASTM A312/A312M—Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes.
  - ASTM A335/A335M—Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service.
  - ASTM A351/A351M—Standard Specification for Steel Castings, Austenitic, for High-Temperature Service.
  - ASTM A387/A387M—Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum.
  - ASTM A403/A403M—Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings.
  - ASTM A490—Specification for Heat-Treated, Steel Structural Bolts, 150 ksi Tensile Strength.
  - ASTM A672—Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures.
  - ASTM B43—Specification for Seamless Red Brass Pipe Standard Sizes.

- ASTM B61—Standard Specification for Steam or Valve Bronze Castings.
- ASTM B62—Composition Bronze or Ounce Metal Castings.
- ASTM B75/B75M—Specification for Seamless Copper Tube.
- ASTM B88—Standard Specification for Seamless Copper Water Tube.
- ASTM B111—Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock.
- ASTM B209—Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate.
- ASTM B462—Specification for Forged or Rolled UNS N08020, UNS N08024, UNS N08026, UNS N08367, and UNS R20033 Alloy Pipe Flanges, Forged Fittings, and Valves and Parts for Corrosive High-Temperature Service.
- ASTM C195—Specification for Mineral Fiber Thermal Insulating Cement.
- ASTM C411—Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation.
- ASTM C533—Specification for Calcium Silicate Block and Pipe Thermal Insulation.
- ASTM C547—Specification for Mineral Fiber Pipe Insulation.
- ASTM C612—Specification for Mineral Fiber Block and Board Thermal Insulation.
- ASTM D1248—Specification for Polyethylene Plastics Molding and Extrusion Materials.
- ASTM D1785—Specification for Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds.
- ASTM D2241—Specification for Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series).
- ASTM D2513—Thermoplastic Gas Pressure Pipe, Tubing and Fittings.
- ASTM D2517—Reinforced Epoxy Resin Gas Pressure Pipe and Fittings.
- ASTM D3350—Specification for Polyethylene Plastics Pipe and Fittings Materials.
- ASTM F441/F441M—Specification for Chlorinated Poly Vinyl Chloride (CPVC) Plastic Pipe, Schedules 40 and 80.

- ANSI—American National Standards Institute:
  - ANSI/ASME B1.1—Unified Inch Screw Threads (UN and UNR thread form).
  - ANSI/ASME B16.1—Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800 lb.
  - ANSI/ASME B16.5—Pipe Flanges and Flanged Fittings, Steel Nickel Alloy and Other Special Alloys.
  - ANSI/ASME B16.9—Factory-Made Wrought Steel Buttwelding Fittings.
  - ANSI/ASME B16.10—Face-to-Face and End-to-End Ferrous Valves.
  - ANSI/ASME B16.11—Forged Steel Fittings Socket-Welding and Threaded.
  - ANSI/ASME B16.15—Cast Bronze Threaded Fittings Classes 125 and 250.
  - ANSI/ASME B16.21—Nonmetallic Flat Gaskets for Pipe Flanges.
  - ANSI/ASME B16.22—Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings.
  - ANSI/ASME B16.24—Bronze Pipe Flanges and Flanged Fittings, Class 150 and 300 lb.
  - ANSI/ASME B16.25—Buttwelding Ends.
  - ANSI/ASME B16.28—Wrought Steel Buttwelding Short Radius Elbows and Returns.

- ANSI/ASME B16.34—Valves-Flanged, Threaded and Welding End.
- ANSI/ASME B18.2.1—Square and Hex Bolts and Screws, Inch Series.
- ANSI/ASME B31.1—Power Piping.
- ANSI/ASME B31.8— Gas Transmission and Distribution Piping.
- ANSI/ASME B36.1 OM—Welded and Seamless Wrought Steel Pipe.
- ANSI/ASME B36.19M—Stainless Steel Pipe.
- ANSI/ASME B73.IM—Specifications for Horizontal End Suction Centrifugal Pumps for Chemical Process.
- ANSI/ASME B133.1M—Procurement Standards for Gas Turbines.
- ANSI/AWWA C110/A21.10—Ductile-Iron and Grey-Iron Fittings, 3 inch through 48 inch (75 mm through 1200 mm) for Water and Other Liquids.
- ANSI/AWWA C111/A21.11—Rubber Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.

- ASME—American Society of Mechanical Engineers:
  - ASME Section I—Rules for Construction of Power Boilers.
  - ASME Section VIII—Rules for Construction of Pressure Vessels.
  - ASME Section IX—Qualification Standard for Welding and Brazing Procedures, Welders, Brazer, and Welding and Brazing Operators.
  - ASME PTC-4.4—Gas Turbine Heat Recovery Steam Generators (R. 1192).
  - ASME PTC-22—Power Test Code for Gas Turbine Power Plants.

- AWS—American Welding Society:

  Welding procedures and qualifications for welders would follow the recommended practices and codes of the AWS.

  - AWS-D1.1—Structural Welding Code-Steel.

- AWWA—American Water Works Association:
  - AWWA-C110—Ductile Iron and Gray Iron Fittings, 3 inches through 48 inches for Water and Other Liquids.
  - AWWA-C111—Rubber-Gasket Joints for Ductile-Iron and Grey Iron Pressure Pipe and Fittings.
  - AWWA-C301—Prestressed Concrete Pressure Pipe, Steel-Cylinder Type For Water and Other Liquids.
  - AWWA-C304—Design of Prestressed Concrete Cylinder Pipe.
  - AWWA-C502—Dry-Barrel Fire Hydrant.
  - AWWA-C504—Rubber Seated Butterfly Valves.
  - AWWA-C906—Polyethylene Pressure Pipe and Fittings, 4 inches through 63 inches for Water Distribution.
  - AWWA-D100—Welded Steel Tanks for water Storage.
  - AWWA-M1 1—Water Supply Practices, Pipe – Design and Installation.

- CGA—Compressed Gas Association Standards.

- CTI—Cooling Tower Institute Standards.

- EEI—Edison Electric Institute Standards.

- EJMA—Expansion Joint Manufacturers Association Standards.
- FCI—Fluid Controls Institute.
- FCI 70-2—Quality Control Standard for Control Valve Seat Leakage.
- HEI—Heat Exchange Institute:
  - Performance Standards for Liquid Ring Vacuum Pumps.
  - Standards and Typical Specifications for Deaerators.
  - Standards for Closed Feedwater Heaters.
  - Standards for Power Plant Heat Exchangers.
  - Standards for Steam Jet Vacuum Systems.
  - Standards for Steam Surface Condensers.
- HI—Hydraulic Institute:
  - ANSI/HI 1.1-1.5—Centrifugal Pumps Nomenclature, Definitions, Applications and Operation
  - ANSI/HI 1.6—Centrifugal Pump Tests
  - ANSI/HI 2.1-2.5—Vertical Pumps Nomenclature, Definitions, Application and Operation
  - ANSI/HI 2.6—Vertical Pump Tests
  - ANSI/HI 9.1-9.5—Pumps-General Guidelines Types, Definitions, Application and Sound Measurements.
- IGCI—Industrial Gas Cleaning Institute Standards.
- MIL—U.S. Department of Defense - Military Specification:
  - MIL-1-24244C Amendment 3—Insulation Material, with Special Corrosion, Chloride, and Fluoride Requirements.
- MSS—Manufacturers Standardization Society of the Valve and Fittings Industry:
  - MSS-SP-25—Standard Marking System for Valves, Fittings, Flanges and Unions.
  - MSS-SP-42—Class 150 Corrosion-Resistant Gate, Globe, Angle, and Check Valves with Flanged and Butt-Weld Ends.
  - MSS-SP 55—Quality Standard for Steel Castings-Visual Method.
  - MSS-SP 67—Butterfly Valves.
  - MSS-SP 80—Bronze Gate, Globe, Angle and Check Valves.
  - MSS-SP-91—Guidelines for Manual Operation Valves.
- NACE—National Association of Corrosion Engineers Recommended Practices.
- NFPA—National Fire Protection Association Codes:
  - ANSI/NFPA 10, Portable Fire Extinguishers.
  - ANSI/NFPA 12, Carbon Dioxide Extinguishing Systems.
  - ANSI/NFPA 13, Installation of Sprinkler Systems.
  - ANSI/NFPA 14, Installation of Standpipe and Hose Systems.
  - ANSI/NFPA 15, Water Spray Fixed Systems.
  - ANSI/NFPA 20, Installation of Centrifugal Fire Pumps.
  - ANSI/NFPA 22, Water Tanks for Private Fire Protection.

  - ANSI/NFPA 24, Private Fire Service Mains and Their Appurtenances.
  - ANSI/NFPA 26, Supervision of Valves Controlling Water Supplies for Fire Protection.
  - ANSI/NFPA 30, Flammable and Combustible Liquids Code.
  - ANSI/NFPA 37, Stationary Combustion Engines and Gas Turbines.
  - ANSI/NFPA 54, National Fuel Gas Code.
  - ANSI/NFPA 70, National Electrical Code.
  - ANSI/NFPA 72, National Fire Alarm Code.
  - ANSI/NFPA 78, Lightning Protection Code.
  - ANSI/NFPA 255, Method of Test of Surface Burning Characteristics of Building Materials.
  - ANSI/NFPA 85, Fire Protection for Electric Generating Plants.
  - ANSI/NFPA 850, Steam Electric Generating Plants.
  - ANSI/NFPA 1961, Fire Hose.
  - ANSI/NFPA 1962, Care, Use, and Service Testing of Fire Hose Including Couplings and Nozzles.
  - ANSI/NFPA 1963, Screw Threads and Gaskets for Fire Hose Connections.

- PFI—Pipe Fabrication Institute Standards.

- PPI—Plastic Pipe Institute Standards.

- SSPC—Steel Structures Painting Council:
  - SSPC-PA1—Shop, Field, and Maintenance Painting.
  - SSPC-PA2—Measurement of Dry Paint Thickness with Magnetic Gages.
  - SSPC-SP1—Solvent Cleaning.
  - SSPC-SP2—Hand Tool Cleaning.
  - SSPC-SP3—Power Tool Cleaning.
  - SSPC-SP6—Commercial Blast Cleaning.
  - SSPC-SP8—Pickling.
  - SSPC-SP10—Near-White Blast Cleaning.

- TEMA—Tubular Exchanger Manufacturers Association Standards.

- UBC—Uniform Building Code:
  - Chapter 3, Classification of All Buildings by Use or Occupancy and General Requirements for All Occupancies.
  - Chapter 6, Type 11 One-Hour and 11-N Buildings.
  - Chapter 10, Exits.
  - Chapter 15, Roof Construction and Covering.
  - UL—Underwriters' Laboratories Standards.

- UPC – Uniform Plumbing Code

3.0 Reliability Codes and Standards

The design and specification of work will be in accordance with the laws and regulations of the federal government, the state of California, and with local codes and ordinances. The

following laws, ordinances, codes, and standards have been identified as applying to power plant reliability, design, and construction. In cases where conflicts between cited codes (or standards) exist, the requirements of the more conservative code will be met.

Federal

- None are applicable.

State

- Both the Warren-Alquist Energy Resource Conservation and Development Act, Public
- Resources Code (PRC) Section 25000 et seq., and the California Energy Commission (CEC)
- Siting Regulations require the applicant to submit detailed information describing measures proposed to ensure the safe and reliable operation of the facility and the design and feasibility of all systems and components related to the generation of power (PRC Sections 25511 and 25520).

County

- None are applicable.

Industry Codes and Standards

There are no industry codes or standards that govern power plant reliability; however, there are trade organizations or associations that are generally recognized as authorities and leaders in the field of power plant availability and reliability. Definitions used by these organizations have become generally accepted as a common means of communicating and the data published have been found useful. The organizations are as follows:

The Electric Power Research Institute (EPRI)
P.O. Box 50490
Palo Alto, CA 94303
Telephone (415) 965-4081

North American Electric Reliability Council (NERC)
Research Park
Terhune Road
Princeton, NJ 08540-3573
Telephone (609) 924-6050

Other recognized standards will be used as required to serve as design, fabrication, and construction guidelines when not in conflict with the above listed standards.

The codes and industry standards used for design, fabrication, and construction will be the codes and industry standards, including all addenda, in effect as stated in equipment and construction purchase or contract documents.

4.0 Mechanical Engineering General Design Criteria

The systems, equipment, materials, and their installation will be designed in accordance with the applicable codes; industry standards; and local, state, and federal regulations; as well as the design criteria; manufacturing processes and procedures; and material selection, testing, welding, and finishing procedures specified in this section.

Detailed equipment design will be performed by the equipment vendors in accordance with the performance and general design requirements.

4.1 HRSGs

HRSGs will be sized in accordance with the heat balances. The HRSG design will meet the requirements of the ASME Boiler and Pressure Vessel Code, Section I, ASME Boiler and Pressure Vessel Code, ASME B31.1, and other applicable codes and standards. Access design and egress requirements for the HRSGs will meet the requirements of NFPA and OSHA.

4.2 STG

The STG will be sized in accordance with the heat balances. STG design will meet the requirements of the ASME Boiler and Pressure Vessel Code, ASME TDP-1, and other applicable codes and standards.

4.3 Pumps

Pumps will be sized in accordance with industry standards. Where feasible, pumps will be sized for maximum efficiency at the normal operating point. Pumps will be designed to be free from excessive vibration throughout the operating range.

4.4 Tanks

Water storage tanks will be designed in accordance with API or AWWA. Large outdoor storage tanks will be non-insulated except where required to maintain appropriate process temperatures or for personnel protection. Overflow connections and lines will be provided. Maintenance drain connections will be provided for complete tank drainage. Manways will be at least 18 inches in diameter and hinged to facilitate removal. Storage tanks will have ladders and cleanout doors as required to facilitate access/maintenance. Provisions will be included for proper tank ventilation during internal maintenance.

4.5 Heat Exchangers

The air cooled condenser and cooling water heat exchanger will be sized based on the heat balances and equipment manufacturer heat loads. The condenser and cooling water heat exchanger will be designed in accordance with HEI, ASME Boiler and Pressure Vessel Code, and TEMA.

4.6 Pressure Vessels

Pressure vessels will be designed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division I. Pressure vessels will include all necessary vent, drains, process connections, manways, and relief valves.

4.7 Piping

Piping will be designed, selected, and fabricated in accordance with the following criteria.

4.7.1 Design Temperature and Pressure

The design pressure and temperature for piping will be consistent with conditions established for the design of the associated system.

The design pressure of a piping system generally will be based on the maximum sustained pressure that may act on the system plus 25 psi. All design pressure values will be rounded up to the next 10 psi increment.

The design temperature of a piping system generally will be based on the maximum sustained temperature which may act on the system plus 10° F. The piping design temperature will be rounded up to the next 5° F increment.

Fire water piping will be designed and tested in accordance with NFPA requirements.

4.7.2 General Design and Selection Criteria

Piping will be designed in accordance with the requirements of the Code for Pressure Piping, ASME B31.1—Power Piping, or other codes and standards referenced in Section 2.2 of this Appendix, as applicable.

Minimum wall thicknesses of straight steel pipe under internal pressure will be designed in accordance with Paragraph 104.1.2 of ASME B31.1.

Allowance for variations from normal operation, consideration for local conditions, and transients will be in accordance with Paragraphs 102.2.4 and 102.2.5 of ASME B31.1.

The value of A (thickness allowance) must be selected to compensate for material removed in threading, corrosion, and erosion, and to provide mechanical strength. The following minimum allowances should be applied:

- Special wall piping 2-1/2 inches and larger—The value of A will be 0.0625 inch.
- Schedule wall piping 2-1/2 inches and larger—The value of A will generally be zero except when additional thickness is considered necessary for a specific service.
- Schedule wall piping 2 inches and smaller—The value of A should be selected to provide adequate mechanical strength. An A value of 0.0625 inch is suggested, but is not mandatory.
- Threaded piping—The value of A will equal the depth of thread.

The pressure temperature ratings for plain end seamless schedule wall pipe will be based on minimum wall values which are 87-1/2 percent of the nominal pipe wall thicknesses with

the value of A equal to zero. This will make allowance for the minus 12-1/2 percent manufacturing tolerance on wall thickness.

The pressure temperature ratings for fusion welded, or forged and bored, schedule wall pipe will be based on the appropriate manufacturing tolerances and the required A value.

Material selection will generally be based on the design temperature and service conditions in accordance with the following:

- Carbon steel piping materials will be used for design temperatures less than or equal to 750° F.
- ASTM A335 Grade P22 or P91 steel piping materials will be used for design temperatures greater than 750° F.
- Five percent chromium alloy steel piping materials will be used where flashing may occur.
- Stainless steel piping materials will be used as follows:
  - Piping applications requiring a high degree of cleanliness generally including miscellaneous lubricating oil system piping and sampling piping after process isolation valves.
  - Piping generally subjected to highly corrosive service applications.
- Fiberglass reinforced plastic piping materials will be used only in applications requiring corrosion-resistant materials.
- Plastic piping having a high coefficient of thermal expansion will be used only after a thorough analysis of the piping system thermal expansion parameters.

The above listed materials, or other suitable piping materials listed in Section 2.3, will be used where required for special service to meet specific requirements. Materials selected for use with main cycle systems will be free of copper materials to allow the cycle to be treated at the optimum pH for corrosion protection of carbon steel components.

4.7.3 Miscellaneous Piping Design and Selection Criteria

The minimum pipe size and wall thickness for miscellaneous piping, other than instrument primary piping, will generally be in accordance with the following criteria:

- The pipe size for piping, except as described above, with a design pressure of 600 psi or less, and with a design temperature of 750° F or less, will be 1/2 inch minimum.

The wall thickness for piping 2 inch nominal size and smaller will be Schedule 80 for carbon steel and alloy pipe, and Schedule 40S for stainless steel pipe minimum.

4.7.4 Instrument Primary Piping Design and Selection Criteria

Instrument primary piping will generally be designed in accordance with the following criteria:

- Piping and instrument diagrams will indicate the size and selection information for piping through the root valves. The line sizes and selection information of tubing piping after the root valves will not be called out on the piping and instrument diagram. The size requirements for instrument primary piping are stated in Appendix J4.
- Pressure connections and piping through the root valves for all pressure indicators, pressure switches, pressure transmitters, etc., will be 3/4 inch.
- Temperature indicators, temperature controllers, temperature switches, temperature detectors, and test well connections will be 3/4 inch NPT.
- Flow transmitter connections and piping through the root valves will be 1 inch for all piping except orifice flanges, where 1/2 inch piping and valves will be used.
- Level switch connections and piping through root valves will be 1 inch.
- Level controllers and level transmitters of the displacement type will have connections and piping through root valves of 2 inches.
- Level controllers and level transmitters of the differential pressure type will have connections and piping through root valves conforming to the requirements for miscellaneous piping in Subsection 2.3.3.
- Level transmitters on tanks and vessels will be installed with isolation valves.
- Instrument columns at tanks and pressure vessels will generally be 2 inch minimum.

4.7.5 Vent and Drain Piping Design Criteria

Vent and drain piping will generally be in accordance with the following criteria:

- Vent connections will be provided at all high points in water and oil piping, and all high points in other piping which will be hydrostatically tested.
- Drain connections will be provided at all non-drainable points in water and oil piping, and all other piping which will be hydrostatically tested.
- All vent and drain connections will be provided with isolation valves. Vent and drains will use full ported valves where practical to resist pluggage. Low-pressure water systems with design pressures of 150 psi or less will use ball valves. Other systems will use gate valves. Alternatively, if the use of full-ported valves is not possible, gate valves will be used.
- Vent and drain connections that require frequent operation or which may discharge significant quantities of fluid will be piped to a suitable drain. Vent or drain connections that will normally require operation at a time when hot fluids will be discharged will be piped to a safe termination point (drain funnel or floor area discharge). All other vent and drain connections will be capped.

4.7.6 Piping Materials

Piping materials will be in accordance with applicable ASTM and ANSI standards. Materials to be incorporated in permanent systems will be new, unused, and undamaged. Piping materials will generally be in accordance with the following criteria:

- Carbon steel piping 2-inch nominal size and smaller will be ungalvanized ASTM A106, Grade B minimum.
- Carbon steel piping 2.5 inch through 26-inch nominal size will be ungalvanized ASTM A53 Grade B seamless or A106 Grade B, with the indicated grades as a minimum. Carbon steel piping larger than 26 inch nominal size will be ASTM A672 Grade B70, Class 21, for steam service, and ASTM A134 (with ASTM A283 Grade C plate material) for cold water service, with the industrial grades as a minimum.
- Alloy steel pipe, including large diameter special wall pipe, will be ungalvanized seamless type. Alloy steel pipe with a 1.25 percent chromium content will conform to ASTM A335, Grade P11. Alloy steel pipe with 2.25 percent chromium content will conform to ASTM A335, Grade P22. Alloy steel pipe with 5 percent chromium content will conform to ASTM A335, Grade P5. Alloy steel pipe with 9 percent chromium content will conform to ASTM A335, Grade P91.
- Stainless steel pipe will be ASTM A3l2 Grades TP 304, TP 304L, TP 316, or TP 316L piping. All stainless steel piping materials will be seamless and fully solution annealed prior to fabrication. The Type 316 materials will be utilized for high resistance to corrosion. The Type 316L materials will be utilized for applications requiring hot working (welding, etc.), when the piping will handle solutions that are high in chlorides.
- Schedule numbers, sizes, and dimensions of all carbon steel pipe will conform to ASME B36.10. Sizes and dimensions of stainless steel pipe designated as Schedule 10S, 40S, or 80S will conform to ANSI B36.19. Schedule numbers, sizes, and dimensions of stainless steel pipe not designated as 10S, 40S, or 80S will conform to ASME B36.10.
- Galvanized carbon steel piping will be ASTM A53 Grade B. The piping will be hot-dip galvanized. The use of galvanized steel pipe will be limited to systems where a high degree of cleanliness is required or where codes require the use of galvanized steel pipe rather than black steel pipe.
- Lining materials for rubber lined carbon steel pipe, method of application, and lining manufacturer will be chosen in accordance with service requirements
- Steel plate piping will be of the welded straight seam type.
- Mechanical joint or push-on joint ductile iron pipe will conform to ANSI/AWWA C151/A21.51. Flanged ductile iron pipe will conform to ANSI/AWWA C115/A21.15.
- Copper alloy pipe will conform to ASTM B43, Seamless Red Brass Pipe.
- Polypropylene lined pipe will be ASTM A53 steel pipe with an applied liner of polypropylene.

- Fiberglass Reinforced Plastic (FRP) pipe will be chosen in accordance with the specific service requirements.
- Polyvinyl Chloride (PVC) pipe will conform to ASTM D1785 or ASTM D2241.
- Chlorinated Polyvinyl Chloride (CPVC) pipe will conform to ASTM F441 or ASTM F442.
- High density polyethylene (HDPE) pipe will conform to ASTM D3350 with a Plastic Pipe Institute rating of PE 3406 or 3408.

4.7.7 Tubing Materials

Tubing materials will generally be in accordance with the following criteria:

- Copper Tubing—Copper tubing 3/8 inch and smaller will be light drawn temper tubing conforming to ASTM B75. Copper tubing, 1/2 inch and larger, will be ASTM B88 Type K drawn temper. Copper tubing will be oxygen-free or phosphorus deoxidized copper. Oxygen bearing tough pitch copper tubing will be used.
- Stainless Steel Tubing—Stainless steel tubing will conform to ASTM A213, Type 316 seamless. All stainless steel tubing will be of the fully annealed type, with a carbon content greater than 0.04 percent. Stainless steel tubing for use with tubing fittings will not exceed Rockwell B80 hardness.
- Tubing Wall Thickness—Wall thickness for tubing 3/4 inch and smaller, not protected by enclosures, will not be less than the following. Heavier wall tubing will be used where required for specific design pressure and temperature conditions:

Wall Thickness

Outside Diameter of Tubing (inch)	Stainless Steel (inch)
1/4	0.035
3/8	0.035
1/2	0.049

4.7.8 Fitting Materials

Fittings will be constructed of materials equivalent to the pipe with which they are used:

- Steel Fittings—Steel fittings 2-1/2 inches and larger will be of the butt welding type, and steel fittings 2 inches and smaller will be of the socket welding type, except galvanized steel fittings will be threaded.
- Butt Welding Fittings—The wall thicknesses of butt welding fittings will be equal to the pipe wall thickness with which they are used. The fittings will be manufactured in accordance with ASME B16.9, ASME B16.28, and ASTM A234 or ASTM A403.
- Forged Steel Fittings—Forged steel fittings will be used for socket-weld and steel threaded connections and will conform to ASME B16.11. The metal thicknesses in the

fittings will be adequate to provide actual bursting strengths equal to or greater than those of the pipe with which they are used.

The minimum class rating of socket-weld and threaded fittings used with various pipe schedules will be as follows:

	Minimum Fitting Class Ratings	
Pipe Schedule No.	**Threaded**	**Socket Welding**
80 or less	2,000	3,000
120 or 160	3,000	6,000
Double extra strong	6,000	9,000

- Cast Steel Flanged Fittings—Cast carbon steel flanged fittings will conform to ASME B16.5 and will be of materials conforming to ASTM A216 WCB.
- Adapters—Specially designed adapters may be used in lieu of reducing outlet tees for the run and branch sizes specified. Specially designed adapters must be postweld heat treated as specified in ASME B31.1. Specially designed adapters will be Weldolets or Sweepolets as manufactured by Bonney Forge and Tool Works, WFI, or equal.
- Branch connections 2 inches and smaller will be made with special reinforced welding adapters, Bonney Forge and Tool Works Thredolets or Sockolets or equal, or will be special welded and drilled pads.
- Ductile Iron Fittings—Mechanical joint or push-on joint ductile iron fittings will conform to ANSI/AWWA C110/A21.10 and ANSI/AWWA C111/A21.11. Flanged ductile iron fittings will conform to ANSI/AWWA C110/A21.10.
- Cast Iron Fittings—Cast iron fittings will conform to ASTM A126, Class B.
- Brass and Bronze Fittings—Screwed brass and bronze pipe fittings will conform to ASME B16.15. Flanged brass and bronze pipe fittings will conform to ASME B16.24.
- Fiberglass Reinforced Plastic (FRP) Fittings—Fittings for use with FRP pipe will be manufactured from material of the same type as the pipe. Joints will be as required by the application. Filament wound or molded fittings will be used as required by the application.
- Polyvinyl Chloride (PVC) Fittings—PVC pipe fittings will be manufactured from PVC material of the same type as the pipe with which they are used. The fittings will have socket ends with internal shoulders designed for solvent cementing.
- Chlorinated Polyvinyl Chloride (CPVC) Fittings—CPVC pipe fittings will be manufactured from CPVC material of the same type as the pipe with which they are used. The fittings will have socket ends with internal shoulders designed for solvent cementing.

- Tubing Fittings—Stainless steel fittings will be used with stainless steel tubing. Fittings for use with stainless steel tubing in sizes smaller than 3/4 inch will be of the flareless "bite" type. Fittings for use with tubing in sizes 3/4 inch and larger will be socket-weld type conforming in general design to ASME B16.11. Fitting material and bursting strength will be equivalent to the tubing with which they are used.

4.7.9 Flanges, Gaskets, and Unions

Flanged joints will be in accordance with the following requirements:

- Flanges mating with flanges on piping, valves, and equipment will be of sizes, drillings, and facings, which match the connecting flanges of the piping, valves, and equipment. Flange class ratings will be adequate to meet the design pressure and temperature values specified for the piping with which they are used. Flanges will be constructed of materials equivalent to the pipe with which they are used.
- Steel flanges will conform to ANSI B16.5. Carbon steel flanges will be of ASTM A105 material. Carbon steel flanges will not be used for temperatures exceeding 750° F.
- Chromium alloy steel and stainless steel flanges will conform to ASTM A182.
- Brass and bronze screwed companion flanges will be plain faced and will conform to Class 150 or Class 300 classifications of ANSI B16.24. Drilling will be in accordance with ANSI Class 125 or Class 250 standards.
- Compressed fiber gaskets will be used with flat face flanges and raised face slip-on flanges.
- Spiral wound gaskets will be used with raised face flanges, except for raised face slip-on flanges. Gaskets containing asbestos are not acceptable.

Gaskets will be suitable for the design pressures and temperatures:

- Compressed fiber gaskets will be in accordance with ANSI B16.21, and materials will be suitable for a maximum working pressure of 600 psi and a maximum working temperature of 75° F.
- Spiral wound gaskets will be constructed of a continuous stainless steel ribbon wound into a spiral with non-asbestos filler between adjacent coils.
- Rubber gasket materials will be cloth inserted sheet rubber and will conform to ANSI B16.21.

4.7.10 Cathodic Protection

Underground carbon steel, stainless steel, copper, or brass piping will be electrically isolated from aboveground piping and other metallic components, and will be provided with a bonded, dielectric coating system to allow the underground piping to be cathodically protected. Isolation from aboveground piping will be achieved by installation of isolation flanges with insulating gaskets, sleeves, and washers. For piping 2 inches and smaller, insulating unions may be used for isolation from aboveground piping. Cathodically

protected piping routed into concrete foundations will be isolated from reinforcing steel with a wrapping of polyethylene mesh over the coating system.

4.7.11 Piping Fabrication

Piping fabrication will generally be in accordance with the requirements of the Piping Fabrication Institute (PFI) and ASME B31.1.

Welding procedures, welders, and welding operators will be qualified in accordance with code requirements. Backing rings will not be used for shop or field welds except where specifically permitted.

4.7.11.1 Inspection and Testing

Inspection and testing of piping will be performed in accordance with the requirements of the applicable code and in accordance with the following criteria.

Pressure testing of piping assemblies, including hydrostatic, pneumatic, and in-service leak testing, will be performed on the system assemblies upon the completion of erection. Shop leak testing of piping will not be required. All underground piping to be tested will be given the test prior to covering the line. Testing will be performed in accordance with the following methods:

- Hydrostatic testing of all piping, except as otherwise discussed herein or for which a pneumatic leak test will be provided, will be performed with cold water at 1-1/2 times the design pressure of the piping.

Piping for which isolation by valving or blanking is impractical (open ended vents and drains after the last valve, safety valve vent stacks, etc.) will not be hydrostatically tested. Piping between isolation valves and connected equipment that is not leak tested will not be hydrostatically tested. Piping connected to equipment that is leak tested will be hydrostatically tested at the lowest test pressure of items involved in that test (pumps and discharge piping to the first isolation valve will be tested at the pump suction piping test conditions, if the suction test conditions are lower). Temporary piping for use only during construction will not be hydrostatically tested.

- Pneumatic testing will be provided for all pressure piping that should not be subject to water filling. This will generally include the following piping:
  - Lube oil piping.
  - Low-pressure (design pressure less than or equal to l50 psi) compressed gas piping conveying natural gas and ammonia.
  - Compressed air piping.
  - Instruments will be carefully protected against overpressure during testing of piping.
- In-service leak testing will be performed for all pressure piping that is not hydrostatically or pneumatically tested by tests that are in full accordance with the applicable code.

Nondestructive testing will generally include visual, radiographic, magnetic particle and liquid penetrant, and ultrasonic examinations:

- Visual examination of welds will be performed by personnel qualified and certified in accordance with AWS QC1, Standard for Qualification and Certification of Welding Inspectors.
- Radiographic examination will be performed on welds requiring examination under the applicable code.
- Magnetic particle and liquid penitrant examination will be performed as required by the applicable code.
- Ultrasonic tests will be performed as required by the applicable code.

4.7.12 Pipe Supports and Hangers

The term "pipe supports" includes all assemblies such as hangers, floorstands, anchors, guides, brackets, sway braces, vibration dampeners, positioners, and any supplementary steel required to attach pipe supports.

4.7.12.1 Design and Selection Criteria

All support materials, design, and construction will be in accordance with the latest applicable provisions of the Power Piping Code, ASME B31.1. Seismic design of piping systems will be in accordance with criteria as stipulated by the Uniform Building Code.

Structure attachment components will be fastened by welding or bolting. Pipe supports will be attached to concrete by cast-in-place anchor bolts, studs, expansion bolts, or plates. Expansion bolts with a minimum pullout safety factor of five will be used. Expansion bolts will be cone-expansion type, conforming to Federal Specification FF-S-325, Group II, Type 4, Class l or 2. Minimum thickness of cast-in-place steel plate bearing against concrete will be as follows:

Supported Pipe Size (nominal inches)	Plate Thickness (inch)
4 and smaller	1/4
6	3/8
8	1/2
10 through 18	3/4
20 and larger	1

Pipe attachments will be rigid relative to the piping and insulation and will extend sufficiently outside insulation, if any, to permit free installation and operation of other support components. Insulation protection saddles or components will be used where required to prevent damage to insulation. On piping other than steel or iron, the piping manufacturer's recommendations will be followed.

Material for clamps, lugs, bolts, studs, and nuts will be carbon steel for piping 750° F or less, and will be alloy steel for piping more than 750° F. Piping attachments for nonmetallic pipe will meet the following minimum requirements:

- The minimum recommendations of the piping manufacturer will be met.
- Piping attachments will not bear load by a point. Their width will equal or exceed the square root of the outside diameter of the piping (thus, 4 inch OD piping minimum clamp width equals 2 inches), and they will bear around 120 degrees or more of the circumference.
- In general, clamps will not be clamped tight and hard on the piping. Where piping attachment must grip the piping by clamping, a soft, Shore 50-60 rubber pad will be provided between the clamp and the piping, and the clamp will be formed to fit the padding.

The top surface of riser clamps will be flat and normal to the pipe.

Riser lugs will be sized in accordance with Welding Research Council Bulletin No. 198 and the requirements of ASME B31.1.

Trapezes will be constructed from structural tubing or from double channels positioned back-to-back with space between for the hanger rods and with washer plates welded to channel tops and bottoms. Washer plates shall be used at all hanger rod attachment points.

Hanger rods will be constructed of solid round steel bars. Maximum allowable stress in a rod will be 9,000 psi average at the thread root cross-sectional area, or 12,000 psi in nonthreaded rods. Pipe, strap, chain, or other similar materials will not be permitted in place of rods.

Screw threads will be in conformance with ASME B1.1. Stress areas for threaded rods will be equal to or larger than the following American National Standard Unified Inch Screw Thread Series:

Nominal Rod Diameter (inches)	Thread Series
3/8 through 4	UNC
4-1/4 and larger	4 UN

Bolting will consist of either studs and nuts or bolts and nuts. Minimum thread engagement will be 100 percent of the nut thread. Nuts for each stud will be installed equidistant from the ends of the stud. Middle portions of studs and shank portions of bolts will not be threaded. Bolt heads and nuts will be hexagonal type, conforming to ASME B18.2. Where no axial load is to be carried, pins with washers and cotter pin retainers will be permitted in place of bolts.

Restraints, struts, and anchors will have the following features:

- Restraints fabricated of structural steel will have a clearance of 1/8 inch, with respect to the restrained component, in the directions of the restrained movement unless otherwise noted.
- All restraints will be designed to withstand the static and kinematic friction due to relative movement of the pipe with respect to the restraints.
- All restraints and anchors will withstand the design loading indicated without buckling.
- All struts will be provided with means for locking the length adjustment. The length adjustment lock will be on the right-hand thread end, if both right- and left-hand threads are used.

Exposed components of shop fabricated pipe supports will be shop painted before shipment to the jobsite. Before painting, surfaces will be suitably cleaned and prepared in accordance with the paint manufacturer's instructions. Bearing surfaces and nameplates will not be painted. These surfaces will be coated with an easily removable rust-preventive compound.

4.7.12.2 Pipe Support and Hanger Materials

Support component materials will be suitable for service at the operating temperature of the pipe to which they are attached. Where support component temperature is below 750° F, component material will be carbon steel or of an ASTM type having a minimum yield strength of 35,000 psi, and a minimum ultimate strength of 58,000 psi.

4.8 Valves

Valve pressure classes, sizes, types, body materials, and end preparations will generally be as described herein. Special features and special application valves will be utilized where required.

Valves specified to have flanged, socket-welded, or screwed connections will have ends prepared in accordance with the applicable ANSI standards. Steel flanges will be raised face type unless otherwise required. Cast iron and bronze flanges will be flat faced type. Butt welding ends will be prepared in accordance with ASME B16.25 and ASME B31.1.

Steel body gate, globe, angle, plug, and check valves will be designed and constructed in accordance with ASME B16.34 as applicable. Valve bodies and bonnets will be designed to support the valve operators (handwheel, gear, or motor) with the valve in any position, without external support.

4.8.1 Steel Body Valves 2 Inches and Smaller

Steel body valves 2 inches and smaller will have forged steel bodies. Forged steel valves complying with the standards and specifications listed in Table 126.1 of ASME B31.1 will be used within the manufacturer's specified pressure temperature ratings and will be limited in accordance with the pressure temperature ratings specified in ANSI B16.34.

- Valve ends will be socket-weld type unless otherwise required.
- Except as otherwise required, check valves will be of the guided piston or swing disk type. All check valves will be designed for installation in either horizontal piping or vertical piping with upward flow.

4.8.2 Steel Body Valves 2-1/2 Inches and Larger

Steel body valves 2-1/2 inches and larger will have cast or forged steel bodies. The face-to-face and end-to-end dimensions will conform to ASME B16.10. Selection of these valves will be in accordance with the pressure temperature ratings specified in ASME B16.34 as applicable:

- Body ends will be butt weld or flanged type.

Check valves will be of the guided piston, swing disk, or double disk spring check type. The use of double disk spring check valves will be limited to cold water services. All check valves will be designed for installation in either horizontal or vertical piping with upward flow.

4.8.3 Iron Body Valves

Iron body gate, globe, and check valves will have iron bodies and will be bronze mounted.

The face-to-face dimensions will be in accordance with ASME B16.10. These valves will have flanged bonnet joints. Gate and globe valves will be of the outside screw and yoke (OS&Y) construction. Body seats will be of the renewable type. Gate valves will be of the wedge disk type.

4.8.4 Butterfly Valves

Rubber-seated butterfly valves will be generally constructed in accordance with AWWA C504 Standard for Rubber-Seated Butterfly Valves. The valves will also generally conform to the requirements of MSS Standard Practice SP-67, Butterfly Valves. Valves of the wafer or lugwafer type will be designed for installation between two ANSI flanges. Valves with flanged ends will be faced and drilled in accordance with ASME B16.1. The selected use of butterfly valves will be in accordance with the pressure temperature ratings specified in AWWA C504, the pressure temperature ratings specified by the manufacturer, and as specified in the following criteria:

- Butterfly valves will generally be used for 4 inch and larger cold water services only.
- Butterfly valves for buried service will be of cast iron body material and will be equipped with flanged ends.
- Cast iron butterfly valves will have pressure classes selected based on the piping design pressure as follows:

Piping Design Pressure	Valve Class
25 psi and below	Class 25
Above 25 psi to 75 psi	Class 75
Above 75 psi to 150 psi	Class 150

Cast iron butterfly valves will be limited to use with piping systems having a design temperature of 125°F or less.

- Butterfly valves for other than buried service will be of carbon steel or cast iron body material depending on the service application. Valves will be of the wafer type, or lugwafer type, if used with steel or alloy steel piping.
- Carbon steel butterfly valves will be limited to use with piping systems having a design temperature of 150°F or less. Carbon steel butterfly valves will have pressure classes selected in accordance with the pressure temperature ratings specified in ASME B16.34 for 24 inch and smaller valves.

Metal seated or teflon seal ring seated butterfly valves for special service applications will be of the wafer or lugwafer type and will be designed for installation between ANSI flanges. The use of these valves will be in accordance with the pressure temperature ratings specified by the manufacturer.

4.8.5 Bronze Body Valves

Bronze gate and globe valves 2 inches and smaller will have union bonnet joints and screwed ends. Gate valves will be inside screw, rising stem type with solid wedge disks. Globe valves will have renewable seats and disks.

Bronze check valves 2 inches and smaller will be Y-pattern swing disk type or guided piston type designed for satisfactory operation in both horizontal piping and vertical piping with upward flow.

Bronze valves 2-1/2 inches and larger will have bolted flange bonnet joints and flanged ends. Gate and globe valves will be of the outside screw rising stem construction. Gate valves will have either integral or renewable seats. Globe valves will have renewable seats.

The use of these valves will be in accordance with the pressure temperature ratings specified by the manufacturer. Bronze valves will be limited to service with piping systems having design pressures of 200 psi or less, and design temperatures of 150° F or less.

Bronze valves will generally be limited to a size of 3 inches or less.

4.8.6 Ball Valves

All ball valves will be in accordance with the pressure temperature ratings specified by the manufacturer. Ball valve bodies 2 inches and smaller will have threaded end or socket-weld connections. Ball valves 2-1/2 inches and larger will have flanged ends. The valves will not require lubrication. Ball valves for use with copper piping shall have brazed or screwed ends. Ball valves for natural gas service shall have renewable seats and be firesafe per API 601 as a minimum.

4.8.7 Diaphragm Valves

Diaphragm valves will be straightaway or weir bodies with flanged ends faced and drilled for installation between ANSI flanges. The use of these valves will be in accordance with the pressure temperature ratings specified by the manufacturer.

4.8.8 Plug Valves

Plug valves will be in accordance with the pressure temperature ratings specified by the manufacturer. All valves will be suitable for the intended service. Plug valve bodies 2 inches

and smaller will be socket weld, screwed, or flanged. Plug valves 2-1/2 inches and larger will be butt weld or flanged.

4.8.9 Polyvinyl Chloride (PVC) and Chlorinated Polyvinyl Chloride (CPVC) Valves

PVC and CPVC valves will be constructed entirely from polyvinyl chloride, chlorinated polyvinyl chloride, and teflon. The use of these valves will be in accordance with the pressure temperature ratings specified by the manufacturer.

4.8.10 3.8.10 Valve Materials

Valve bodies will generally be constructed of materials equivalent to the pipe with which they are used. Valve body and trim materials of construction will be in accordance with applicable ASTM and AISI standards. Valve body materials will generally be as follows:

Material Name	Description	
Cast Iron	ASTM A126 Class B	
Bronze	ASTM B61 or ASTM B62	
	Forged	**Cast**
Carbon Steel	ASTM A105	ASTM A216 Grade WCB
Stainless Steel	ASTM A182 Grade F316L or Grade F316	ASTM A351 Grade CF3M or Grade CF8M

4.8.11 Valve Operators

Valves will be provided with manual or automatic operators as required for the service application and system control philosophy. Automatic operators will be motor, piston, or diaphragm type.

Manual operators will be lever, handwheel, or gear type, with the use of lever operators to be limited to valves requiring a maximum of 90 degree stem rotation from full open to full closed position on valve sizes 6 inches and smaller. All operators will be sized to operate the valve with the valve exposed to maximum differential pressure.

4.8.12 Branch Line Isolation Valves

An isolation valve will be provided in 2 inch and smaller branch lines from major headers.

4.8.13 Valve Special Features

Valves will be provided with locking devices, handwheel extensions, vacuum service packing, limit switches, and other special features as required. Locking devices, when furnished, will allow the valve to be locked either open or closed with a standard padlock. Limit switches, when furnished, will be provided for the open and closed position of the valve.

Valves (control) will not be equipped with bypasses unless specifically required.

4.9 Insulation and Lagging

The insulation and lagging to be applied to piping, equipment, and ductwork for the purposes of reducing heat loss, reducing sweating, and personnel protection will be in accordance with the following criteria.

4.9.1 Insulation Materials and Installation

Insulation materials will be inhibited and of a low halogen content so that the insulation meets the requirements of MIL-I-24244 Amendment 3 regarding stress-corrosion cracking of austenitic stainless steel. Insulation materials will contain no asbestos.

All piping operating above 140°F will be insulated with calcium silicate molded insulation in accordance with ASTM C533, fiberglass, or mineral fiber, dependent on the application.

Equipment and ductwork operating at elevated temperatures will be insulated with calcium silicate block fiberglass, or mineral fiber block insulation dependent on the application.

Mineral fiber block insulation for use on equipment surfaces will be in accordance with ASTM C612, Class 3, and have a density of 8 to 12 pcf.

Insulating cements will be mineral fiber thermal insulating cements and will confirm to ASTM C195.

4.9.2 Lagging Materials and Installation

All insulated surfaces of equipment, ductwork, piping, and valves will be lagged. All aluminum lagging will be ASTM B209 Alclad 3004 or acceptable equal. All aluminum lagging will be stucco pattern embossed.

4.9.3 Insulation Supports for Piping

Vertical runs of piping, which will be insulated, will utilize support lugs and collars to prevent slippage of the insulation.

4.9.4 Insulation Classes for Piping and Equipment

Piping and equipment insulation classes and corresponding thicknesses are designated by letters, which will be indicated in the design documents.

The insulation for piping accessories will be of the same class as is indicated for the piping. Insulation materials for miscellaneous piping and equipment will be suitable for the actual operating temperatures.

For piping systems operating above 140° F where the retention of heat is not necessary for proper operation, such as vents and various drains, the insulation thickness shall be reduced to that necessary to maintain the surface temperature of the insulation at approximately 140 F.

4.9.5 Freeze Protection

All aboveground water and steam piping will be arranged to allow drainage to protect the piping from freezing. The piping systems will be arranged to minimize the amount of piping requiring drainage for freeze protection. Certain small bore piping and tubing applications exposed to freezing conditions will be heat traced and insulated.

4.9.6 Anti Sweat Insulation

All aboveground cold water and air piping will be provided with anti sweat insulation.

APPENDIX 2A.4

Control Engineering Design Criteria

APPENDIX 2A.4

Control Engineering Design Criteria

1.0 Introduction

Control of the design, engineering, procurement, and construction activities on the project will be completed in accordance with various predetermined standard practices and project-specific programs and practices. An orderly sequence of events for the implementation of the project is planned consisting of the following major activities:

- Conceptual design.
- Licensing and permitting.
- Detailed design.
- Procurement.
- Construction and construction management.
- Startup, testing, and checkout.
- Project completion.

The purpose of this appendix is to summarize the codes and standards and standard design criteria and practices that will be used during the project. These criteria form the basis of the design for the control systems of the project. More specific design information will be developed during detailed design to support equipment and erection specifications. It is not the intent of this appendix to present the detailed design information for each component and system, but rather to summarize the codes, standards, and general criteria that will be used. Codes, standards, and general criteria selected during the detail design phase of the project may vary from the information indicated in this appendix in accordance with specific project or design requirements. The lead control engineer will authorize all variations in design criteria.

Section 2.0 summarizes the applicable codes and standards and Section 3.0 includes the general design criteria for general conditions, instruments, modulating type control systems, motor controls, and control equipment locations.

2.0 Codes and Standards

The design specification of all work will in accordance with the laws and regulations of the federal government and the state of California, and applicable local codes and ordinances. A summary of general codes and industry standards applicable to design and construction follows:

- American National Standards Institute (ANSI).
- American Society of Mechanical Engineers (ASME).
- American Society for Testing and Materials (ASTM).
- The Institute of Electrical and Electronics Engineers (IEEE).

- Instrument Society of America (ISA).
- National Electric Code (NEC).
- National Electric Manufacturers Association (NEMA).
- National Electric Safety Code (NESC).
- National Fire Protection Association (NFPA).
- Scientific Apparatus Makers Association (SAMA).
- California Referenced Standards Code, 2001 edition as amended by the City of (Later).
- California Energy Code, Title 24 of the California Code of Regulations.
- California Electrical Code, 2004 edition and Uniform Administrative Code Provisions for the National Fire Code, 1996 as amended by the City of (Later).
- Other recognized standards will be utilized as required to serve as design, fabrication, and construction guidelines when not in conflict with the above listed standards.
- The codes and industry standards used for design, fabrication, and construction will be the codes and industry standards, including all addenda, in effect as stated in equipment and construction purchase or contract documents.

3.0 Control Systems Design Criteria

3.1 General Requirements

3.1.1 Ambient Conditions

All instrument and control devices will be designed to withstand ambient conditions appropriate to their mounting location or be suitably protected. The evaluated operating conditions for instruments and control devices installed in heated/air-conditioned areas will include air conditioning failures.

3.1.2 Power Supplies

All instruments and control devices will be designed to operate on power supplies as follows:

- Electric:
  - 120 volt AC, 60 hertz, single-phase for control logic (digital input interrogation voltage), motor control center (MCC), solenoid valve, and low torque drives with guaranteed satisfactory operation when equipment is continuously energized at any voltage from 100 to 132 volts AC.
  - 125 volt DC for logic, control (switchgear) and low torque drives.
  - 480 volt AC, 60 hertz, 3-phase for high torque drives.
  - Any voltage required other than the above will be furnished by the equipment supplier.

- Pneumatic: Clean, dry, and oil free instrument air at 70 to 125 psig. All necessary pressure reducing controls (pressure regulators), where required, will be furnished by the equipment supplier.

3.1.3 Standard Ranges of Analog Signals

The ranges of analog signals will normally be as follows:

- Electric—4 to 20 mA DC
- Pneumatic—3 to 15 psig
- Thermocouple—Type K
- RTD—100 ohm platinum

The use of any signal range other than the above will be avoided.

3.1.4 Contact Ratings

The rating of all instrument contacts used for alarm and interlocking will be coordinated to meet the requirements of the interfacing/interlocking system. The ratings of all solid-state control system output contacts will be coordinated to meet the requirements of the driven device/equipment. Consideration will be given to the voltage and current rating, continuous rating, maximum rating (break), and switch rating (break).

In general, the ratings of all instrument contacts used for alarms and interlocks will have a minimum rating as follows:

Voltage Rating, Volts	Continuous Rating, Amperes	Maximum Rating (Break), Amperes	Switching Rating (Break)
120 AC	5.0	3.0	360 volt-amperes
125 DC	2.5	0.50	63 watts

The ratings of all microprocessor output contacts will be the manufacturer's standard rating.

3.2 Instruments

Instrument housings will be in accordance with the NEMA, or other project designated authority rating for the area in which the instrument is located.

3.2.1 Instrument Primary Piping/Tubing (Impulse Lines)

Instrument primary piping/tubing is defined as the piping directly connected to the process, beginning at the outlet of the root valve and terminating at the blowdown valve, and at the point of connection to the instrument.

The preferred material for installation of instrument primary tubing is stainless steel tubing using grip type fittings.

Piping will be used exclusively for all measuring devices to be supported on connecting piping. Stainless steel tubing will be used for all other instrument primary lines. Socket weld fittings will be used on tubing having 0.083 inch or greater wall thickness. Grip type fittings will be used on tubing with wall thickness 0.065 inch or less. Changes in instrument primary

tubing direction for tubing having 0.083 inch or greater wall thickness will use tube fittings. All other tubing will be bent.

Pressure test points will have isolation valves and caps. Temperature test points will have thermowells, caps, and plugs.

3.2.1.1 Sizes of Instrument Primary Piping/Tubing

Instrument primary piping will not be smaller than the connection at the process pipe root valve and/or the following:

- Pressure measurement will use primary tubing conforming to the requirements below.
- Flow and level measurement by differential pressure will use primary tubing conforming to the requirements below; however, flange tap connections may be of 0.5 inch size.
- Float actuated level switch devices will be supported on connecting piping not smaller than 1 inch.
- Level controllers and transmitters of the displacement float or guided wave radar type will be supported on connecting piping not smaller than 2 inches.
- Instrument columns for float actuated level switches, displacement float devices, or guided wave radar devices will be piping of not less than 2 inches.
- Primary piping/tubing internal diameter shall not be less than 0.330 inch between the process connection and instrument blowdown valve.
- Instrument tubing will be 0.5 inch OD with wall thickness of 0.083 inch, 0.065 inch, or 0.049 inch as required by the primary piping design pressure and temperature.
- When instrument manifolds are furnished, 0.25 inch outside diameter stainless steel flexible metal hoses, rated for the process design temperature and pressure, may be used as a flex line (less than 18 inch length) between the instrument manifold and the instrument. Direct manifold mounting of the instrument to the manifold is preferred.

3.2.1.2 Materials for Instrument Primary Piping

Material for connecting from the process header to the root valve will preferably be the same as that used in the process system to which it is connected. Material for instrument primary tubing will be stainless steel, ASTM A213 GR TP316. Higher strength materials may be substituted in the interest of standardization; however, welding procedures at the point of joining the instrument primary piping/tubing to the process piping must be appropriate to the combination of materials involved. Copper or brass may be used only for compressed air or for water services that use copper or brass process piping.

3.2.1.3 Insulation of Instrument Primary Piping/Tubing

Instrument primary piping or tubing connecting to high temperature systems, which might become hot enough to injure personnel during blowdown of the instrument line, will be insulated where such hazard exists. Insulation materials, exterior finish, and metal lagging will conform to the standards adopted for the process piping.

3.2.1.4 Criteria for Routing of Instrument Primary Piping/Tubing

Routing of instrument primary piping or tubing, including piping from the process connection through the root valve and the instrument primary piping or tubing, will be in accordance with the following criteria.

Special fittings such as reservoirs and other devices will be installed at differential pressure element connections as required by the process parameter to be measured and by the design of the instrument, in accordance with instructions of the instrument supplier.

Instrument primary piping or tubing for steam flow, liquid flow, and manometer level measurement systems should slope downward from the primary element connections to the instrument. Instrument primary piping or tubing for fuel gas, compressed air, flue gas and airflow measurement systems should slope upward from the primary element connections to the instrument. If these requirements cannot be met, special venting, drain, or seal provisions will be required. Horizontal runs must have a slope of not less than 0.5 inch per foot and must be adequately supported to maintain a constant slope.

Pressure taps will be located on the top or sides of gas, or air piping, and on the bottom (15 degrees from dead center bottom) or side of liquid filled or steam piping. Pressure taps on boiler gas and air ducts will be located on the top or side to permit draining condensation.

3.2.1.5 Support of Instrument Piping/Tubing

Instrument primary piping will be supported in accordance with support requirements for process piping. Instrument primary tubing will be continually supported using unistrut, angle iron, or tubing tray. Pneumatic signal and air supply tubing will be continuously supported and will normally be provided by tubing tray.

3.2.2 Thermowells and Protecting Tubes

Fluid system temperature sensors will be equipped with threaded thermowells and will be made of one-piece, solid bored Type 316 stainless steel of stepless tapered design. Threaded temperature wells in lines operating above 600 psi will be seal welded after installation.

Thermowells in main steam and feedwater piping will be designed to prevent damage caused by vortex-induced vibration over the range of velocities encountered in normal service in accordance with ASME PTC 19.3.

All thermowells in steam piping will be installed and seal welded after steam blow to avoid exposure to vibration damage. For steam blow, the connections will be plugged by screwed plugs after assuring thermowells can be properly inserted. All other thermowells will be installed prior to hydrostatic testing.

Test wells will be provided on main steam, feedwater, and other piping as required to meet ASME or other project designated test requirements.

Temperature detectors in exhaust gas ducts will be mounted in protecting tubes to provide mechanical support and to permit replacement while in operation. Protecting tubes will be made of Type 316 stainless steel not smaller than 0.5 inch with 1.5-inch screwed pipe bushings tack welded to the tubes for attachment to the duct and insertion adjustments. Duct connections will consist of screwed couplings or adapter flanges welded to the ducts,

into which the bushings on the protecting tubes can be threaded. Duct connections will be located to minimize the effect of temperature stratification within the ducts. Protecting tubes exceeding 3 feet in length shall be provided with additional supports within the boiler casing or ducts.

3.2.3 Thermocouples and Resistance Temperature Detectors

Temperature measurements for remote use will be by temperature detectors. Temperature detectors will preferably be thermocouples. Thermocouples should be chromel-alumel, Type K, with Type KX extension cable. Thermocouples and extension cable will comply with the standard limits of error in accordance with ANSI MC 96.1 (latest revision). The elements as a rule will be separate from ground (ungrounded).

Resistance temperature detectors (RTDs) will be of the three-wire, 100-ohm platinum type. The nominal resistance of the platinum detectors will be 100 ohms at 0 degrees C. All RTDs for measurement of fluid system temperature will be ungrounded, metal sheathed, ceramic packed, and suitable for the design temperature, pressure, and velocity of the fluid system.

Thermocouples and RTDs will have sheathed elements spring-loaded to provide good thermal contact with the well or protecting tube. The sheath will be made of stainless steel and have swaged type magnesium oxide insulation. All connection heads will be weatherproof, with screwed covers, and supported from the well by a stainless steel extension nipple, extending at least six inches outside the insulation.

3.2.4 Transmitters

Transmitters will be used to provide the required 4 to 20 mA DC signals for all control systems. Transmitters will be of the electronic two wire type, capable of driving a load up to 750 ohm, designed with provisions for zero and span adjustments, and will have ±0.25 percent accuracy or better. Pressure and differential pressure type transmitters will have ±0.1 percent accuracy or better.

3.2.4.1 Static Pressure and Differential Pressure Transmitters

Sensing elements for static pressure and differential pressure transmitters will be of either the capacitance, strain gauge, or resonant frequency type.

For steam and water services, static pressure transmitters will be equipped with a two-valve manifold, and differential pressure transmitters will be equipped with a three-valve manifold. Manifolds will be constructed in accordance with ASME B31.1. Direct manifold mounting of the instrument to the manifold is preferred.

3.2.4.2 Level Transmitters

Sensing elements for level transmitters will be of the following types:

- Static head devices for vessels exposed to atmospheric pressure; air bubbler type devices may be used if absorption of air by the liquid is not objectionable. (Level transmitters of this type are the same as static pressure transmitters.)
- Differential pressure type with constant head chamber for high-pressure and temperature applications where installation of guided wave radar or float cage becomes impractical. (Level transmitters of this type are the same as differential pressure transmitters.) Tank level installations will include flanged isolation valves.

- Displacement float type, guided wave radar type, or differential pressure type for feedwater heaters and enclosed vessels (where practical).
- RF admittance, guided wave radar, or ultrasonic type, for specialized applications.

3.2.4.3 Flow Transmitters

Flow transmitters for general applications will be of the differential pressure type:

Primary Elements. Flow nozzles will be used for feedwater flow, steam flow and other critical measurements where weld-in construction is required. Flow nozzles will be made of stainless steel with dual sets of pressure taps installed in the pipe wall where required. Installation of flow nozzles and pressure taps will be made in the flow element manufacturer's shop as required. Feedwater flow and steam flow nozzles will be calibrated by a nationally recognized feedwater and steam flow calibrating facility.

Paddle type orifice plates will be used for other flow measurements where flanged construction and higher pressure loss are acceptable. Orifice plates will be made of stainless steel. Orifice flanges will be of the raised face weld neck type with dual sets of taps.

Construction and installation of flow nozzles and orifices will conform to the requirements of ASME Performance Test Code PTC 19.5, and discharge coefficients will be predicted in accordance with data published in ASME Research Report on Fluid Meters by ASME.

Airfoil or venturi flow sections, or averaging type pitot tubes, may be used for measuring boiler combustion airflow.

Thermal dispersion meters, piezometers, and averaging pitot tubes will be used for measuring flows in large pipes or ducts where installation of flow nozzles, orifice plates, or airfoils is impractical.

Secondary Elements. Secondary elements for differential type primary flow elements will be differential pressure transmitters as described above. Square root extraction required for the DP transmitters will be performed electronically in the control system, which receives the transmitter output signal.

Positive displacement type flowmeters will be used for measuring fuel oil flows.

Turbine or vortex flowmeters or orifice type flow sections will be used for measuring gas flows.

3.2.5 Temperature, Pressure, Level, and Flow Switches

Temperature, pressure, level, and flow switches will generally have two single-pole, double-throw (two Form C contacts) for each actuation point. Each switch will have screw type or compression type terminals to accept field wiring no smaller than 16 AWG.

Where standard switch ranges allow, switches will be applied so that the actuation point is within the center one-third of the instrument range. Switch set point will be adjustable. Contacts will be of the snap-acting type.

3.2.5.1 Temperature Switches

Temperature switches will be actuated by filled-bulb type elements equipped with standard length armored capillary tubing.

3.2.5.2 Pressure Switches

Pressure switches will be actuated by diaphragm type elements. Pressure switches will be classified into the following types:

- General static pressure switches and general differential pressure switches for normal static pressure ranges.
- Low differential pressure switches for low static pressure ranges.
- Low differential pressure switches for high static pressure and/or applications requiring both indication and pressure switch contacts.

3.2.5.3 Level Switches

Level switches will be actuated by elements of the following types:

- Static head devices for vessels exposed to atmospheric pressure; air bubbler type devices may be used if absorption of air by liquid is not objectionable. Level switches of this type are the same as static pressure switches.
- Differential type for high pressure and high temperature applications. Level switches of this type are the same as differential pressure switches.
- Displacement float type or differential type for enclosed vessels and sumps.
- Moving float or ultrasonic type for open tanks and sumps.
- Capacitance, RF admittance, or ultrasonic type, for specialized applications.

Switching elements of moving float and displacement float type level switches will have float and body construction appropriate to the service conditions of the systems to which they are connected. Switch elements shall be of the vibration resistant, snap-acting type magnetically coupled to the float. Two switch elements or one DPDT switch element will be available at each level point monitored.

Each switch element will be reversible for NC or NO operation, or will be double-throw construction. Switch element leads will be of high temperature construction as required, and terminated on terminal blocks within the switch housing. Switch housing will be NEMA 4 construction, unless otherwise specified.

3.2.5.4 Flow Switches

Variable area or differential pressure type actuating elements will be used for low-flow and low-pressure applications.

3.2.6 Local Indicators

3.2.6.1 Local Temperature Indicators (Thermometers)

Thermometers for local mounting will be 4.5 inch dial with white faces and black scale markings, bimetal actuated thermometers, or acceptable equal. Thermometers for panel mounting will be gas-actuated with stainless steel armored capillary tubing of the length required for installation with 4.5 inch minimum dial size. Dial scales will be such that the normal operating range is in the middle third of the dial range. The dials will be engraved with service legends, or separate nameplates will be furnished to identify the service. Separate nameplates shall be engraved phenolic attached to the dial face or stamped

stainless steel attached to the thermometer by stainless steel wire. Thermowells will be furnished for all thermometers.

3.2.6.2 Local Pressure Indicators (Pressure Gauges)

Gauges for control air supply and signal pressures integral to an instrument will be in accordance with the instrument manufacturer's standards. All other gauges will be 4.5 inch minimum dial size or acceptable equal. All gauges will have stainless steel movements. Gauges for panel mounting shall be of the flush mounting type. Gauges for separate mountings shall have 0.5 inch NPT bottom connections.

Dial scales will be such that the normal operating range is in the middle third of the dial range. In general, pressure indicators will have linear scales with units in psig. The dials will be engraved with service legends, or separate nameplates will be furnished to identify the service. Separate nameplates shall be engraved phenolic attached to the dial face or stamped stainless steel attached to the thermometer by stainless steel wire.

Gauges for fluids which may be corrosive to the gauge internals will be furnished with glycerin filled cases and diaphragm seals. Gauges on pulsating services will have pulsation dampeners. Gauges used in compressed gas applications or those equipped with diaphragm seals will not be furnished with pulsation dampeners. Gauges required by a specific code, such as NFPA 20, will be supplied in accordance with the code.

3.2.6.3 Local Level Indicators (Gauge Glasses)

Tubular gauge glasses will be used for low-pressure applications. Transparent or reflex gauges will be used for high-pressure applications. All gauge glasses will be equipped with gauge valves, including a safety ball check.

3.2.6.4 Flow Indicators

Sight flow and variable flow indicators will be only be used for low pressure and low temperature applications where quantitative measure of flow is not required.

Flow indicators for high-pressure and high temperature applications are not anticipated.

3.2.7 Solenoid Valves

Solenoid coils will generally be high temperature construction and will be designed for continuous duty. Three-way solenoid valves will be designed for universal operation so that the supply air may be connected to any port. Solenoid enclosures will be NEMA 4.

3.3 Plant Control Systems

3.3.1 Pneumatic Controllers

The use of pneumatic controllers will be minimized but may be used for the following applications:

- Control loops which require only proportional or proportional plus reset action, but require no remote manual positioning by the control room operator.
- Control loops that do not require any interface with any receiver installed in the control room.

3.3.2 Electronic Control Systems

The objective of the control and information systems is to facilitate plant operations by ensuring personnel safety, equipment protection, adequate operation, and plant availability. The control and information systems will ensure these criteria are met by incorporating the following design features:

- Centralized control location(s).
- Reasonably consistent operator interface.
- Redundancy of key critical components.
- Fail-safe design of protective systems.
- Cost-effective design.

The majority of plant equipment control and information functions will be implemented in the Distributed Control System (DCS). The major exceptions are controls for the combustion and steam turbines.

3.3.2.1 Combustion and Steam Turbine Controls

All combustion and steam turbine controls will be performed in the proprietary control systems furnished by the turbine suppliers. The combustion turbine control systems and steam turbine control systems will interface with the DCS through redundant datalinks and a limited complement of hard-wired I/O for operator actions and information display; however, the equipment control and protection logic will be implemented in the proprietary control systems provided by the respective equipment suppliers. In addition to the local controls provided for the combustion and steam turbines, and the information furnished to the DCS via datalinks and hard wiring, workstations should be provided for the proprietary turbine control systems in the control room.

3.3.2.2 DCS Equipment Function

The DCS will be a microprocessor-based system and will provide modulating control, digital control, monitoring, alarming, logging, data archiving, and indicating functions for the plant systems. The following functions will be provided:

- Overall control of the combustion turbine generator, heat recovery steam generator (HRSG), steam turbine generator, and other systems in a coordinated response to unit load demands.
- Sequential combined cycle plant startups and shutdowns initiated by the plant operators.
- Control of the balance-of-plant process equipment, including the steam-feedwater-condensate cycle, auxiliary cooling water, water quality control systems, cycle chemical feed system, and other process systems.
- Operator interface for the turbine generator controls for normal or automatic operation.
- Operator interface for the auxiliary electric system.
- Visual and discernible audible alarms for abnormal events based on field signals or software generated signals from the systems, processes, or equipment.

- Consolidated sequence-of-events recording for each combustion turbine, steam turbine, and balance-of-plant systems to assist with diagnostic evaluation of plant upsets and trips.
- Provide operator interface through control consoles consisting of CRTs and printers.
- On-line hardware and software diagnostics.
- On-line programming and logic changes with tuning capability.
- Monitor plant equipment and process parameters and provide this information to the plant operators in a meaningful format.

3.3.2.3 Major DCS Components

The DCS will include the following equipment:

- Distributed I/O cabinets containing the system input/output equipment and wiring terminations for process sensing and control equipment interface. These I/O cabinets will be located in areas of high concentration of field equipment that interfaces with the DCS.
- Distributed processing unit cabinets containing the redundant processing units, data highway communications equipment, and power supplies.
- Communication interfaces between the DCS and proprietary control systems furnished with major equipment packages.
- Redundant data highway to provide communication between the various components of the DCS. The redundant data highway cables will be routed through separate raceway systems to provide proper isolation.
- Operator workstations, each composed of color CRTs and a cursor control (trackball or mouse), to provide the normal interface between the operator and the plant processes and equipment being controlled or monitored. Alarm functions will also be displayed on these work stations.
- Printers to provide the operator with a hard copy record of logs, reports, system events, and CRT displays.
- Operator/Engineer's workstation containing the CRT-based, operator/engineer station to provide the interface between the plant engineer and the plant processes and equipment for control system tuning, system program development and modification, and CRT graphic display development and modification. A printer will also be located on the console to provide the engineer logs and special reports, and documentation of system programming changes.
- Facilities for historical storage and retrieval will also be provided. Both analog values and digital status information will be stored. Each data point will have an individually selectable collection frequency.

Control systems supplied with individual vendor's equipment will, to the extent practical, be designed to be integrated into the plant DCS.

Operator workstation displays will provide manual/automatic control station interface to the modulating control system. The displays will provide for operator adjustments of set point, bias, output, and manual/automatic control switching and indication of the associated station status and process values.

Operator workstation displays will also provide start and stop or open and close commands to motor-operated equipment. Running, stopped, open, closed, and automatic trip status feedback and automatic/standby mode status will be displayed for the operator.

3.3.2.4 DCS Functional Distribution

The DCS will be composed of functionally distributed redundant (modular) processors, input/output modules, and operator interface devices, all connected via a redundant communications network Each system component connected to the communications network will be assigned a specific control or information task. All components will have the capability to communicate with one another through the communications network.

3.3.2.5 DCS Inputs and Outputs

Input/output modules will be used for interfacing with transmitters and other sensors, final control elements, motor starters, breakers, and other plant equipment located throughout the plant. The I/O modules containing inputs and outputs used for control functions will be connected directly to the individual control processors so that a failure of the communications network will not affect the availability of the inputs and outputs necessary for execution of the control functions of the system.

Where control information is transmitted between processors via the data highway, the overall security and response times of the control loops and digital control operations will be evaluated for acceptability. To the extent practical, the system will be organized so that the program within a processing unit will stand alone without dependence upon another processing unit or loop communications.

3.3.2.6 Workstations

CRT based operator workstations will be provided in sufficient quantities to allow for ease of operation of the plant control systems.

Each operator workstation will be designed for point-and-click initiation of operator control commands. "Hard-wired" devices such as push buttons and indicators will be limited to those required by codes and regulations, and those necessary for hard-wired emergency shutdown push buttons in the unlikely event of control system failure.

3.3.2.7 DCS Failure Mitigation and Reliability

The DCS will be designed so that no single failure of any equipment or power source will interrupt or disrupt any control function, nor will any single failure cause any controlled equipment to change status unless specifically required in accordance with the design. System outputs controlling redundant or parallel process equipment will be assigned to minimize the impact of an output card failure. In general, the use of redundant DCS outputs will be avoided. In cases of a failure of a single system input transducer or of an input module serving only that transducer, a predicted DCS system control response to the failure will be allowable. All such failures, however, will be alarmed.

The DCS design will incorporate functional and component redundancy to ensure maximum reliability during system operation. Each of the processing units performing control and alarm functions will contain a pair of completely duplicate processors. One processor of the pair will be active; the other processor will be operating in a hot standby mode and will be continuously updated to be aware of the status of the active processor. In the event of a failure in the active processor, all functions will instantly be assumed by the standby processor. The transfer to the standby processor will be alarmed.

The system configuration will be such that no single component failure of the communication network will degrade other components within the system.

Redundant and secure power supplies will be provided for all control components in the system. Peripheral devices such as printers and copiers will be powered from a vital power source in the plant.

3.3.2.8 DCS Diagnostics

The DCS will be equipped with a diagnostic package that includes both hardware and software to detect system malfunctions and equipment failure. The occurrence of any malfunction or equipment failure will be alarmed instantly. The diagnostic package will be capable of pinpointing the defective component down to the card level.

3.3.2.9 DCS Responses to Failures

The DCS will be designed to react in a predictable manner to certain failures, such as those listed below.

- Upon system logic failure, as detected by system diagnostics, a controller transfers to its backup. If the backup is unavailable, the controller outputs will fail to a predictable state and will enable any manual shutdown facilities which are appropriate to provide orderly shutdown of equipment.
- Upon system logic power supply failure, the controller will transfer to its backup. If the backup is unavailable, the system outputs will fail to a de-energized state.
- Upon power failure to an active or running controlled device or equipment, the system will react in a predetermined manner, either to command a restart of the equipment upon power resumption, or to cycle the logic to a status requiring equipment shutdown.

3.3.2.10 Response Time

The response time of the system will be sufficient to maintain control over the plant processes under all system operating conditions including extreme plant upset conditions with all points in alarm. The response time is the total elapsed time for transmission of data through the system communication path. This time will include all communication time from processor to processor, I/O scans, nodes, gateways, operator work stations, and associated equipment internal to the system. The system response time will be as follows:

Function	Nominal Response (msec)
Monitoring/Information	2,000
Modulating Control	
Slow Loops	1,000

Function	Nominal Response (msec)
Fast Loops	250
Manual Control	1,000
Motor Control	1,000
Sequence-of-Events and Alarm Monitoring	1

3.3.2.11 DCS Expansion

The DCS will include spare capacity and equipment, and provisions for future expansions.

3.3.2.12 DCS Information Presentation

The control systems will provide real-time information to the operators in several formats as follows:

- Process graphic displays—The process graphic displays present information to the operator in formats similar to simplified Piping and Instrument Diagrams or equipment pictorials. Process information and equipment status are presented as dynamic text values and symbol colors. Operator control actions may be affected through the process graphic displays.
- Faceplate displays—Faceplate displays consist of an intelligent grouping of manual/auto stations or control "faceplates" associated with a given piece of equipment or process. Operator control actions will be affected through the faceplate displays.
- Bar chart displays—Bar chart displays consist of a grouping of vertical or horizontal dynamic bar graphs associated with a particular process. Bar charts provide an analog representation of process parameters for quick operator recognition and comparison.
- Trend displays—Trend displays provide a dynamic graphical representation of analog (or discrete) values versus time. Trend displays replace the function of ink type "strip chart" recorders. Trend displays provide the capability to scroll backwards in time to review performance or process trends, thereby assisting in troubleshooting and post-trip analysis.

3.3.2.13 DCS Annunciation

The control systems will annunciate the occurrence of abnormal events in the form of CRT alarm summaries, printed alarm logs, and audible tones.

The operators will be alerted to the occurrence of abnormal events and the return of abnormal events to normal operating conditions. The conditions to be annunciated include those that are potentially dangerous to personnel or damaging to equipment, those that may affect the plant's load carrying capability, and those indicative of processes or equipment that are operating in an abnormal or inefficient condition. Return-to-normal operating conditions will not be annunciated.

The alarm printer will provide a hard copy printout of the alarm conditions that appear on the operator work stations.

3.3.3 Discrete Controls

Motor and other discrete interlocks will be designed in accordance with the following criteria. The logic will be designed to minimize the requirement for operator interface.

3.3.3.1 Protective Interlocks

The protective interlocks for each motor and its associated equipment will be designed as follows:

- To prevent the motor from being started if the starting permissives required for safe operation are not satisfied.
- To automatically stop the motor under unsafe operating conditions when any action by the operator may be too slow to prevent the motor and its associated equipment from being damaged.
- To automatically start any standby equipment as a result of a motor trip and/or as required by the process.
- To provide outputs to inform the operator of the equipment status at all times.
- To provide outputs to alert the operator when any critical operating parameter is approaching its limit or when an abnormal operating condition occurs.
- To prevent operation of generators and transformers when permissives are not met. These will combine hard-wired protective and lockout relays with software protective interlocks.

3.3.3.2 Standby Starts

Components in a system, such as turbine AC and DC lube oil pumps, which are paired to back up each other, will have a standby mode imposed upon the protective interlock scheme. If the redundant pump is in the standby mode when the operating pump is tripped, or a process parameter indicates that the operating pump has failed, the standby pump will standby-start. After a pump has started in the standby mode, the pump will not stop automatically, except on a trip condition. An alarm will be generated to alert the operator that the pump has standby started.

3.3.3.3 Automatic Starts and Stop

Equipment in some systems will operate in an automatic mode in which the starting and stopping of a motor are initiated automatically. An example of the automatic mode is a tank fill pump that automatically starts at a low level and stops at a high level. Automatic motor actuations will not be alarmed unless the automatic action is initiated by a protective interlock. Normal automatic motor actuations will, however, be recorded in the events log and summary display.

3.3.3.4 Manual Control

All equipment will be provided with the manual control mode. Automatic and standby control modes will be provided for equipment as appropriate. Equipment that is not frequently operated, such as auxiliary electric system feeder breakers, or equipment which is normally not started without supervision will only be provided with the manual control mode.

3.3.3.5 Sequential Controls

Sequential controls apply control logic to a system or group of equipment. Its functions are to coordinate the operation of all components in a functional group and to automatically start and stop or open and close all components in a predetermined sequence. The sequence should not require the operator to initiate any step-by-step control during the process. Sequential controls are typically found in vendor-furnished packaged systems, such as demineralizers and water treatment systems, and are generally implemented in programmable logic controllers. Sequential controls should be designed to provide required information via network connection to the DCS, if implemented in vendor-furnished packaged systems.

3.3.4 Hardware Selection

3.3.4.1 Logic System

The main plant controls will utilize DCS type hardware. Controls purchased as part of an equipment package may utilize electromechanical or solid-state hardware, or may be hybrid.

3.3.4.2 Local Control Hardware

Small fans and pumps may be controlled by local control switches, if advantageous, and no intervention is required by the control room operator.

3.3.5 Location of Control Equipment

Control equipment refers to the control devices used to implement the modulating and discrete control strategies, and the equipment provided for operator interface.

All pneumatic controllers will be field-mounted. All other control devices will be either mounted on a control console or panel, in a control cabinet, or on local stands.

Control areas will include the Control Room, local equipment buildings supplied by the combustion turbine and steam turbine supplier, and local areas in which local control stations and local control panels are located.

3.3.5.1 Control Room

The Control Room will contain the DCS, combustion turbine, and steam turbine operator workstations mounted on the control console from which the operator will conduct all normal and emergency operations of the unit. The alarm and log printers will also be located in the Control Room.

3.3.5.2 Electronic Equipment Room

The electronic equipment room for the installation of control equipment, computer cabinets, and other solid-state electronic equipment will be provided in an area adjacent to the Control Room. The electronic equipment room will be environmentally controlled.

3.3.5.3 DCS I/O Locations

All DCS I/O modules and devices will be located in environments compatible with the hardware. Where remote I/O cabinets are used, they will be located in protected, ventilated (or air-conditioned) environments as appropriate for solid-state electronics, in accordance with the manufacturer's recommendations. I/O hardware will be physically distributed where practical to reduce cable costs.

3.3.5.4 Local Control Areas

Local control areas will be established for systems where it is advantageous to have operator control in the vicinity of the equipment being controlled. The combustion turbine controls fall under this category.

Each of these systems will be provided with sufficient local control devices for a local operator to initiate a startup or shutdown sequence with provisions for manual control of major power-operated components within the system independent of the sequential operation.

3.3.6 Final Control Devices

Final control devices will be supplied with the necessary signal conditioning and sensing devices to adequately interface with the control system.

3.3.6.1 Control Valves

Air-operated modulating valves controlled from an electronic control system will be provided with a valve positioner capable of receiving a 4 to 20 mA signal and converting the signal to an air pressure signal corresponding to the force required to move the valve diaphragm to the adjusted position. In certain instances when an electronic-to-pneumatic positioner is not commercially available, a combination of an signal converter (electropneumatic) and pneumatic valve positioner will be supplied.

3.3.6.2 Control Drives

Control drives modulating boiler process dampers and other process related equipment will be capable of receiving a 4 to 20 mA signal. The drive will include integral position switches and/or a position transmitter. The drives and associated linkages will be sized to accommodate the maximum operating force required by the damper or driven equipment. Drive operating speeds will accommodate the process dynamics of the system.

3.3.6.3 Open/Close Air-Operated Valves and Operators

Air-operated open/close valves and operators controlled from the electronic control system will include solenoid valves and open/close position switches. Failure mode will be determined during detailed design.

3.3.6.4 Open/Close Electrically Operated Valves and Operators

Electrically operated open/close/jog valves and operators controlled from the electronic control system will include integral position switches. Valves and operators required to jog (stop in an undetermined, intermediated position) will include position transmitters.

3.3.7 Operator Interface Devices

Operator interface devices, whether workstations or local interface devices will be designed in accordance with ISA Recommended Practice 60.3 and, in particular, the human factors design criteria listed below.

- Safety—Consideration will be given to safety, including minimizing potential human error in the operation or maintenance of plant equipment using the DCS control equipment.
- Standardization—Controls, displays, nomenclature, color selection, and arrangement schemes will be consistent for common functions of all equipment.

- Allocation of Functions—The allocation of control functions between man and machine will be optimized based on study or prior successful experience.
- Ergonomics—The physical design and construction of equipment will give consideration to human engineering ergonomics.
- Interaction—The operator will have all control devices and displays necessary to fulfill his assignment at his disposal and within his reach and visual range.

In consideration of these criteria, provisions will be made for remote (control room) operator interaction with plant systems and equipment, which are routinely started and stopped, adjusted, or require hourly monitoring.

APPENDIX 2A.5

Electrical Engineering Design Criteria

APPENDIX 2A.5

Electrical Engineering Design Criteria

1.0 Introduction

This appendix describes the design criteria which will be used for all electrical work related to this project.

Project design, engineering, procurement, and construction activities will be controlled in accordance with various predetermined standard practices and project-specific programs/practices. An orderly sequence of events for project implementation is planned, consisting of the following major activities:

- Conceptual design.
- Licensing and permitting.
- Detailed design.
- Procurement.
- Construction and construction management.
- Checkout, testing, and startup.
- Project completion.

This appendix also summarizes the codes and standards, standard design criteria, and recommended industrial practices that will be used during the project. The general electrical design criteria defined herein form the basis of the design for project electrical components and systems. More specific design information will be developed during detailed design to support equipment and erection specifications. It is not the intent of this appendix to present the detailed design information for each component and system, but rather to summarize the codes, standards, and general criteria that will be used. Codes, standards, and general criteria selected during the detail design phase of the project may vary from the information indicated in this appendix per specific project or design requirements.

Section 2.0 summarizes the applicable codes and standards, and Section 3.0 includes the general design criteria for motors, power and control wiring, protective relaying, classification of hazardous areas, grounding, lighting, heat tracing, lightning protection, raceway and conduit, and cathodic protection.

2.0 Codes and Standards

The design and specification of all work shall be in accordance with the laws and regulations of the Federal Government and the state of California, including applicable local codes and ordinances. A listing of the applicable local codes and industry recognized general codes and standards to be used in design, construction and testing follows:

- The American Bearing Manufacturers Association (ABMA).
- American National Standards Institute (ANSI).
- American Society for Testing and Materials (ASTM).

- Insulated Cable Engineers Association (ICEA).
- Institute of Electrical and Electronics Engineers (IEEE).
- Illuminating Engineering Society (IES).
- National Electrical Code (NEC).
- National Electrical Manufacturers Association (NEMA).
- National Electrical Safety Code (NESC).
- National Fire Protection Association (NFPA).
- Occupational Safety and Health Administration (OSHA).
- Underwriters' Laboratories (UL).
- Uniform Building Code (UBC).
- American Gas Association (AGA).

Other recognized standards will be used where required to serve as guidelines for design, fabrication, and construction when not in conflict with the above listed standards.

The codes and industry standards used for design, fabrication, and construction will be the codes and industry standards, including all addenda, in effect as stated in equipment and construction purchase or contract documents.

- Seismic design criteria from either the Uniform Building Code or IEEE will be used.

The following laws, ordinances, regulations, and standards (LORS) have been identified as applying to electrical engineering design and construction. In cases where conflicts between cited codes (or standards) exist, the requirements of the more conservative code will be met.

2.1 Federal

None are applicable.

2.2 State

- Title 24 California Code of Regulations (CCR) Sections 2-5301 et seq., Energy Conservation.
- Title 24 CCR Section 2-6101 et seq., Special Electrical Systems.
- Title 24 CCR Section 3-089 et seq., State Electrical Systems.
- Warren-Alquist Act (WAA) and the California Energy Commission (CEC) siting regulations require submittal of detailed information describing measures proposed to ensure safe and reliable operation of the facility and the design and feasibility of all systems and components related to the generation of power.
- California State Building Code
- California Referenced Standards Code, 2001 Edition as amended by the City of (Later).
- California Energy Code, Title 24 of the California Code of Regulations.
- California Electrical Code, 2004 Edition and Uniform Administrative Code provisions for the National Electrical Code, 1996 Edition as amended by the City of (Later).

2.3 County

None are applicable.

3.0 Electric Motors

3.1 General Motor Design Criteria

These paragraphs outline basic motor design guide parameters for selecting and purchasing electric motors. The following design parameters will be considered:

- Motor manufacturer.
- Environment, including special enclosure requirements.
- Voltage, frequency, and phases.
- Horsepower, starting, running and duty cycle requirements and limitations.
- Motor type (synchronous, induction, DC, etc.) and construction.
- Power factor (Starting and Running).
- Service factor.
- Speed and direction of rotation.
- Insulation.
- Temperature limitations of winding insulation and enclosures.
- Accessory devices
- Enclosure
- Bearing construction, rating life of rolling elements, and external lube oil system for sleeve or plate bearings.
- Cooling requirements
- Ambient noise level and noise level for motor and driven equipment.
- Frame size
- Termination provisions for power and grounding conductors and accessories.
- Installation, testing, and maintenance requirements.
- Special features (shaft grounding, temperature and vibration monitoring, surge protection, etc.).
- Motor space heater requirements.

3.1.1 Safety Considerations for Motors

The Occupational Safety and Health Administration rules will be followed for personnel protection. Belt guards will be specified for personnel safety and, when required, to prevent

foreign objects from contacting belt surfaces. Guard screens will be provided over motor enclosure openings to prevent direct access to rotating parts. Electrical motors will be adequately grounded.

Motors in hazardous areas will conform to applicable regulatory requirements and will be UL labeled for the application. For medium voltage motors, electrical connections will be terminated within oversized conduit boxes mounted to the motor frame.

3.1.2 Codes and Standards

Motors will be designed, manufactured, and tested in accordance with the latest applicable standards, codes, and technical definitions of ANSI, IEEE, NEMA, and ABMA. The requirements of each applicable code or standard will be supplemented by requirements of the individual equipment specifications.

3.1.3 Testing Requirements

Each type of AC and DC machine will be tested in accordance with the manufacturer's routine tests at the factory to determine that it is free from electrical or mechanical defects and to provide assurance that it meets specified requirements. The following criteria and tests will be used in testing each type of machine:

- Integral horsepower, three-phase, 460-volt induction motors:
  - Routine tests listed in NEMA MG-1, Routine Tests for Polyphase Medium-Induction Motors
  - Test procedures will be in accordance with IEEE, Test Procedure for Polyphase Induction Motors and Generators
- Induction motors rated above 600 volts:
  - Routine tests listed in NEMA MG-1, Large Machines-Induction Machines-Tests, will be performed on each motor.
  - The following additional tests and inspections will be performed on each motor larger than 500 horsepower:
    - Locked-rotor current at fractional voltage. Current balance.
    - Length of time of bearing test and final temperature rise of bearing.
    - A statement that bearings have been inspected and approved for shipment.
    - Insulation resistance time curve and polarization index for motors with formed-coil stators.
    - Final value of motor noise levels including statement that there is no objectionable single frequency noise.
    - Final air gap measurements (single air gap).

- Motors that are specified to have complete tests performed on either the furnished motor or an electrically duplicate motor will require the following tests:
  - Temperature
  - Percent slip
  - No-load saturation curve
  - Locked-rotor saturation curve, including locked-rotor torque, current, and power
  - Speed-torque and speed-current curves at rated voltage and at minimum starting voltage
  - Efficiency at full, three-fourths, and one-half loads
  - Power factor at full, three-fourths, and one-half loads
- Direct current motors—The standard routine tests and inspections will be performed on each motor. These shall include the following:
  - High potential dielectric test
  - Measurement of resistance of all windings
  - Inspection of bearings and bearing lubrication system.

(1) No-load running armature current, shunt field current, and speed in revolutions per minute, at rated voltage.

(2) Full load armature current, shunts field current, and speed in revolutions per minute, at rated voltage.

Test procedures will be in accordance with NEMA MG-1 Tests and Performance DC Small and Medium Motors.

3.2 Electrical Design Criteria

Special requirements for individual motors and specifications for special application motors will be included in individual specification technical sections.

3.2.1 Rating

The motor nameplate horsepower multiplied by the motor nameplate service factor will be at least 15 percent greater than the driven equipment operating range maximum brake horsepower requirement. For motors with 1.15 service factor, the maximum load break horsepower will not exceed the motor nameplate.

Motor operating voltages (excluding motor-operated valves) are tabulated as follows:

Voltage Horsepower	Nominal System Voltage	Motor Nameplate Voltage	Frequency, Hz	Phases
Up to 1/3	120	115	60	1
1/2 and less than or equal to 249 (except for special applications)	480	460	60	3
250 and larger	4,160	4,000	60	3
DC motors	125	120	DC	—

This table is intended as a general guide; however, individual conditions such as distance from power source, voltage drop, etc., may dictate deviations from the stated horsepower/voltage criteria.

Emergency motors will operate continuously at the nominal system voltage with any supply voltage variation between 80 and 112 percent of the nominal system voltage.

Motors will be designed for full voltage across the line starting and frequent starting where required and will be suitable for continuous duty in the specified ambient conditions. Intermittent duty motors will be selected where recognized and defined as standard by the equipment standards and codes.

The torque characteristics of all induction motors will be as required to accelerate the inertia loads of the motor and driven equipment to full speed without damage to the motor or the equipment at any voltage from 90 to 110 percent of motor nameplate voltage except those to be individually considered. A voltage drop greater than 10 percent from the specified motor nameplate rating will be individually considered for proper motor starting and operating.

3.2.2 Temperature Considerations

Integral horsepower motors will be designed for an ambient temperature of 40°C. Motors located in areas where the ambient temperature exceeds 40°C will be designed for that ambient condition.

3.2.3 Windings and Insulation

All insulated windings will have a Class F nonhygroscopic insulation system with Class B temperature rise and ambient temperature in accordance with NEMA MG-1 standards. When ambient temperatures greater than 40°C are specified, the allowable temperature rise will be reduced in accordance with NEMA MG-1 standards.

All insulated stator winding conductors and wound rotor motor secondary windings will be copper.

The insulation resistance corrected to 40°C will be not less than motor rated kV+1 megohms for all windings.

Where required, the windings will be treated with a resilient, abrasion resistant material.

3.2.4 Overspeeds

Squirrel-cage and wound-rotor induction motors, except crane motors, will be so constructed that, in an emergency of short duration, they will withstand, without mechanical injury, overspeeds above synchronous speed in accordance with the table as listed in NEMA MG-1, Overspeeds for Motors.

3.2.5 Space Heaters

Space heaters will be sized as required to maintain the motor internal temperature above the dew point when the motor is idle. Motor space heaters will not cause winding temperatures to exceed rated limiting values nor cause thermal protective device over temperature indication when the motor is not energized.

In general, all NEMA series 180 frame size motors or larger will have 120-volt, single-phase, 60-hertz space heaters. The voltage rating of the heaters shall be at least twice their operating voltage of 120 volts. All 4,000-volt motors will have space heaters. Space heaters rated 10 amps and less will be suitable for operation on 120 volts, single-phase, 60 hertz. Heaters rated above 10 amps will be suitable for operation on 208 volts, three-phase, 60 hertz. Heaters will be located and insulated so they do not damage motor components or finish.

Space heater leads will be stranded copper cable with 600-volt insulation and shall include terminal connectors. Space heater leads will be wired to a separate terminal housing on 4,000-volt motors.

3.2.6 Nameplates

All motor nameplate data will conform to NEMA MG-1 requirements. The following additional nameplate data will be included for 4,000-volt-rated motors:

- Manufacturer's identification number.
- Frame size number.
- Insulation system class designation.
- Maximum ambient temperature for which the motor is designed or the temperature rise by resistance.
- Service factor.
- Starting limitations.
- Direction of rotation and voltage sequence.
- ABMA bearing identification number for motors furnished with rolling element bearings.
- For motors with connections to an external lubricant recirculating system, or with an integral forced lubrication system, oil pressure and oil flow required.
- For motors designed for service in hazardous areas:
  - Location class and group designation.
  - Maximum operating temperature value or operating temperature code number.

3.2.7 Environment

Location of individual motors within the plant will determine ambient temperature, corrosive environment, hazardous environment, and humidity to be experienced by the motors. These conditions will be considered in the purchase specification.

3.2.8 Allowable Noise

The motor sound level will conform with the motor driven equipment assembly overall sound level requirements. In no case will the average no-load sound pressure level, reference level 20 micropascals, produced by the motor, exceed 90 dBA free field at 1 meter for motors rated 200 horsepower and less and at 2 meters for motors rated above 200 horsepower.

3.3 4,000-Volt Squirrel-Cage Induction Motors

3.3.1 Design and Construction

Design and construction of 4,000-volt motors will be coordinated with the driven equipment requirements.

Motor power lead terminal housings will be adequately sized to terminate the power conductors. The power lead terminal housing will also be large enough to provide working space for field fabrication of stress cones within the housing and to contain the stress cones after installation.

The terminal housings of motors required being equipped with current transformers and neutral connections will have sufficient space for the added equipment.

Separate terminal housings will be provided for:

- Motor power leads.
- Motor accessory leads.
- Motor temperature detector leads.

All leads will be wired into their respective terminal housings. All motor leads and their terminals will be permanently marked in accordance with the requirements of NEMA MG-1, Part 2. Each lead marking will be visible after taping of the terminals.

Motors designed to rotate in only one direction will have the direction of rotation marked by an arrow mounted visibly on the stator frame near the terminal housings or on the nameplate, and the leads marked for phase sequence T1, T2, and T3 to correspond to the direction of rotation and supply voltage sequence.

All outdoor motors will be TEFC with NEMA waterproof features or WP Type II with filter. Indoor motors in wet areas will be fully guarded, with dripproof enclosures.

Motors for outdoor service will have all exposed metal surfaces protected with a corrosion-resistant polyester paint or coating.

In addition to the preceding requirements for outdoor service motors, totally enclosed motors will have enclosure interior surfaces and the stator and rotor air gap surfaces protected with a corrosion-resistant alkyd enamel or with polyester or epoxy paint or coating. Bolts, nuts, screws, and other hardware items will be corrosion-resistant or heavy cadmium plated metal. A rotating labyrinth shaft seal will be furnished on the shaft extension end of the motor.

Weather protected Type II enclosures will have standard space heaters, and removable, recleanable, impingement type air filters.

Squirrel-cage induction motors will have rotors of fabricated copper alloy, cast aluminum, or fabricated aluminum alloy. Fabricated aluminum alloy will only be used where the manufacturer has demonstrated the reliability of his design and low inertia loads.

3.3.2 Insulation

All motors shall be furnished with Class F or Class H insulation systems, provided the temperature rise is based on Class B maximum. An insulation resistance time curve

corrected to 40°C for determining the polarization index for motor stator windings will be taken immediately before making the final high potential ground test. Each stator phase will be tested separately to ground, with other phases grounded. Motors will be tested at not less than 5,000 VDC. The ambient temperature, winding temperature, and relative humidity values will be included with the recorded data. The polarization index will not be less than 3.0. An insulation-to-ground dielectric test will be made on the motor windings at a value of two times rated voltage + 1,000.

3.3.3 Bearings

Horizontal motors, except motors for belted drives, will have split sleeve bearings of oil ring type, unless required otherwise.

Sleeve bearings on horizontal motors will be designed and located centrally with respect to running magnetic center to prevent the rotor axial thrust from being continuously applied against either end of the bearing. The motors will be able to withstand without damage the axial thrusts developed when the motor is energized.

When sleeve bearings are not specified, horizontal motors will have antifriction bearings.

Thrust bearings for vertical motors will be able to operate for extended periods of time at any of the thrust loadings imposed by the specific piece of driven equipment during starting and normal operation, without damage to the bearings, the motor frame, or other motor parts.

Motors furnished with spherical roller thrust bearings will also be furnished with ball or deep groove radial guide bearings. The guide bearings will be locked to the shaft so that the guide bearing will take upward thrust and to assure that the thrust bearing is always loaded. If spring loading is furnished, the guide bearing will not be preloaded during normal operation.

Bearing lubricants will contain a corrosion inhibitor. The type and grade of lubricant will be indicated on a nameplate attachment to the motor frame or end shield adjacent to the lubricant filling device.

Insulation will be provided on bearing temperature detectors and on oil piping connections when required to prevent circulation of shaft current through bearings.

Bearings and bearing housings will be designed to permit disassembly in the field for inspection of the bearings or removal of the rotor.

3.3.4 Bearing Temperature Detectors

One Type E thermocouple per motor bearing, complete with detector head and holder assemblies as required, will be furnished. Thermocouple lead wire insulation will be color-coded with standard colors to represent the thermocouple metals.

3.3.5 Winding Temperature Detectors

Two resistance platinum temperature detectors (RTDs) per winding will be furnished, installed, and wired complete. Temperature detectors will normally be three-wire type RTDs.

3.3.6 Temperature Detector and Terminal Block Requirements

Temperature detectors will be ungrounded, with detector leads wired to terminal blocks furnished in the accessory terminal housings. A grounding terminal for each temperature detector will be included with the detector lead terminals. The grounding terminals will be wired internally to a common ground connection in each terminal box. The internal wiring will be removable.

3.4 460-Volt Integral Horsepower Motors

3.4.1 Design and Construction

Design and construction of each 460-volt integral horsepower motor will be coordinated with the driven equipment requirements and the requirements of NEMA MG1 Standards.

Motors will have TEFC enclosures unless located in hazardous areas.

Motors for service in hazardous areas will be individually considered for type of enclosure depending upon the classification, group, and division of the hazardous area in question.

Motors for outdoor service will have all exposed metal surfaces protected with a corrosion-resistant polyester paint or coating.

Motor power lead terminal housing will be sized to allow for ease in terminating the incoming power cable. Space heater leads will also be in this terminal housing.

3.4.2 Bearings

The motor manufacturer will determine the type of bearings to be furnished based upon the load, speed, and thrust conditions of the driven equipment.

Antifriction bearings will be grease lubricated, designed to minimize the likelihood of over lubricating, shall be sealed to protect against dust entry and loss of lubricant, and shall be self-lubricating and regreaseable.

All bearing mountings will be designed to prevent the entrance of lubricant into the motor enclosure of dirt into the bearings.

Grease fittings for lubrication will be arranged for safe, easy addition of lubricant from the outside of the motor while the motor is in service.

Bearings and bearing housings will be designed to permit disassembly in the field for inspection of the bearings or removal of the rotor.

Horizontal motor bearings will have an L-10 rating life when operating under the load, speed, and thrust requirements of the driven equipment of not less than 40,000 hours for direct coupled or gear driven service and not less than 20,000 hours for belt or chain connected service.

Vertical motor bearings will have an L-10 rating life of not less than 40,000 hours.

3.5 Direct Current Machines

3.5.1 Design and Construction

All direct current machines will be designed and constructed for continuous operation and in accordance with the requirements of NEMA MG-1.

Motors for operation on an AC rectified power source will be rated, designed, and factory tested in accordance with NEMA MG-1 requirements for the form factor of the rectified power source. The rated form factor will be obtained from the rectifier manufacturer.

3.5.2 Service Factor

For motors furnished with a service factor greater than 1.0, the motor nameplate will indicate the horsepower rating at 1.0 service factor, and the service factor. The motor will be designed to provide a continuous horsepower capacity equal to the rated horsepower at 1.0 service factor multiplied by the specified motor service factor without exceeding the total limiting temperature rise stated in these specifications for the insulation system and enclosure specified.

3.5.3 Insulation and Windings

All insulated windings will have a minimum of Class B nonhygroscopic, or acceptable equivalent, sealed insulation system. All insulated winding conductors will be copper.

3.5.4 Armatures and Brushes

Commutator bars will be fabricated of silver bearing copper, free of cracks, pits, slivers, and similar imperfections. Bars will be insulated with mica segments, assembled and seasoned as a unit, properly undercut, and securely mounted on the shaft. The area in back of the armature commutator risers will be packed with an epoxy compound and cured. Coil end connections to the risers will be soldered with high temperature pure tin solder, brazed, or tungsten inert gas welded.

Brush holders will be fabricated of nonferrous materials, located accurately, and mounted securely to position the brushes on the armature. Brush holder pockets will be sized to permit proper movement of the brushes. Means for adjusting brush pressures and brush assembly ring will be provided. A stop device will be furnished to prevent the brush terminal from scoring the commutator.

Brushes will be carbon type and will be furnished with insulated shunts sized for the rated brush current.

Successful commutation in accordance with NEMA standards will be maintained over the load range encountered in service.

Extra large openings will be provided for ease of inspection, pressure adjustment and replacement of brushes, and for brush assembly ring adjustment.

3.5.5 Bearings

All bearings will be self-lubricating, will have provisions for relubrication, and will be designed to operate in any position or at any angle.

3.6 Fractional Horsepower Motors

Type, design, and construction of each general, special, and definite purpose fractional horsepower motor will be coordinated with the driven equipment requirements and will be in accordance with the requirements of NEMA MG-1. Motors will be provided with Class B or Class F insulation classification. Motors for service in hazardous areas will be individually considered for type of enclosure depending upon the classification, group, and division of the hazardous area in question.

Motors will be totally enclosed (TEFC or TENV) unless specified otherwise.

Motors for outdoor service will have all exposed metal surfaces protected, where practical, with a corrosion-resistant polyester paint or coating. Enclosure exterior and interior surfaces, air gap surfaces, and windings will be protected with a corrosion-resistant epoxy paint or coating.

All bearings will be self-lubricating, will have provisions for relubrication, and will be designed to operate in any position or at any angle.

3.7 Motor Operators for Nonmodulating Valve, Gate, or Damper Service

The following requirements are applicable to all electric operators required for nonmodulating motor operators.

3.7.1 Rating, Design, and Construction

Motors will be designed for high torque, reversing service in a 50°C ambient temperature. Motors will have Class F insulation classification. Requirements of NEMA MG-1 and MG-2 will apply.

Motors will be rated 460 volts, three-phase, 60 hertz unless otherwise indicated. The DC motors will be rated 120 volts DC to operate from a nominal 125-volt battery.

The motor time rating for normal opening and closing service will be not less than whichever of the following is greatest:

- As required for three successive open-close operations.
- As required for the service.
- Fifteen minutes at maximum driven equipment torque in a 50°C (122°F) ambient temperature.

Sufficient torque will be provided to operate against system torque at 90 percent nominal voltage for AC motors and at 85 percent nominal voltage for DC motors.

Motors will be provided with NEMA 4 enclosures unless specified otherwise.

Motors for service in hazardous areas will be individually considered for type of enclosure depending upon the classification, group, and division of the hazardous area in question.

3.7.2 Bearings

Double-shielded, grease prelubricated, regreaseable antifriction bearings will be furnished. Motor leads will be terminated in the limit switch compartment.

3.7.3 Space Heaters

All motor operators 7-1/2 horsepower and larger will be supplied with 120-volt AC, single-phase, space heaters. Space heater leads will be terminated in the limit switch compartment.

3.8 Hoist, HVAC, and Miscellaneous Motors

Motors not related to power production will conform to applicable requirements of NEMA MG 1 and will otherwise be manufacturer's standard.

4.0 Power and Control Wiring

4.1 Design Conditions

In general, conductors will be insulated on the basis of a normal maximum conductor temperature of 90°C in 40°C ambient air, with a maximum emergency overload temperature of 130°C and a short-circuit temperature of 250°C. In areas with higher ambient temperatures, larger conductors will be used or higher temperature rated insulation will be selected. Conductor size and ampacity will be coordinated with circuit protective devices. Cable feeders from 4.16 kV switchgear to power equipment will be sized so that a short-circuit fault at the terminals of the load will not result in damage to the cable before normal operation of fault interrupting device (breaker is tripped or fuse is melted).

Instrument cable will be shielded and twisted to minimize electrical noise interference as follows:

- Aluminum-polyester tape with 100 percent coverage and copper drain wire will be used for shielding.
- Low-level analog and digital signal cables will be made up of twisted and shielded pairs.
- Except where specific reasons dictate otherwise, cable shields will be electrically continuous. When two lengths of shielded cable are connected together at a terminal block, a point on the terminal block will be used for connecting the shields.
- For multi-pair cables using individual pair shields, the shields will be electrically isolated from each other.

To be effective, instrument cable shields will be grounded on one end as follows:

- The shield on instrument circuits will typically be grounded at the power supply end, unless directed otherwise by the control equipment supplier.
- The shields on grounded, as well as ungrounded, thermocouple circuits will be grounded at the thermocouple well.
- Multi-pair cables used with thermocouples will have individually isolated shields so that each shield will be maintained at the particular couple ground potential.
- Each resistance temperature detector (RTD) system will be a three-wire system consisting of one power supply and one or more RTDs and will be grounded at only one point.

- RTDs embedded in windings of transformers and rotating machines will be grounded at the frame of the respective equipment.
- The low or negative potential side of an instrument signal pair will be grounded at the same point where the shield is grounded. Where a common power supply is used, the low side of each signal pair and its shield will typically be grounded at the power supply.

4.2 Conductors

4.2.1 Design Basis

Electrical conductors will be selected with an insulation level applicable to the system voltage for which they are used and ampacities suitable for the load being served. The type of cable used will be determined by individual circuit requirements and individual equipment manufacturer's recommendations.

All current carrying conductors, except for thermocouple wiring, will be copper.

4.2.2 Cable Ampacities

The maximum ampacity for any cable will depend upon the worst case in which the cable will be routed (tray, conduit, duct, or direct buried) and the associated NEC ampacity requirements. In addition to ampacity, special requirements such as voltage drop, fault current availability, and environment will be taken into consideration when sizing cable.

4.2.3 Insulation

Cable insulation and construction will be as follows.

4.2.4 Flame Retardance

To minimize the damage that can be caused by a cable fire, cables will have insulations and jackets with non-propagating and self-extinguishing characteristics. As a minimum, these cables will meet the flame test requirements of IEEE, using a gas-burner flame source. These characteristics are essential for cables installed in electrical cable tray in the plant.

4.2.5 Medium Voltage Power Cable

Single conductor shielded power cable, with stranded copper conductor, cross-linked polyethylene (XLPE) or ethylene propylene rubber (EPR) insulation, and flame retardant polyvinyl chloride (FRPVC), flame retardant chlorinated polyethylene (CPE), or flame retardant chlorosulfonated polyethylene (CSP) jacket will be used on service above 2,400 volts.

Shielded power cable with minimum 5 kV class, 133% or 8 kV, 100% insulation level will supply all 4.16 kV service and will be routed in trays, conduits, or underground duct banks.

If required, shielded power cable with minimum 15 kV class, 133% insulation level will supply all 13.8 kV service and will be routed in trays, conduits, or underground duct banks.

4.2.6 Low Voltage Power Cable, 600 Volts

Nonshielded power cable with 600-V thermosetting insulation will supply power to loads at voltage levels of 600 VAC and below and 125 VDC and below. Cables will be routed in trays, conduits, or ducts. Loads requiring 3-phase, 12 to 2 AWG conductors will be fed with

NEC type TC power cable which utilizes three insulated copper conductors, XLPE or EPR insulation, a bare ground wire, and an FRPVC, CPE, or CSP overall jacket.

Loads requiring 1 AWG and larger conductors will be fed with single conductor power cable which uses stranded copper conductor, XLPE or EPR insulation without an overall jacket.

4.2.7 Control Cable 600 Volts

Nonshielded control cable with 600-V-class insulation will be used for 120-volt AC and all DC control, metering, and relaying applications. Cables will be routed in trays, conduits, or ducts.

Direct current circuits, which are routed underground, shall utilize multiple conductor control cable having 10, 12, or 14 AWG stranded copper conductors, XLPE or EPR insulation, and with an FRPVC, CPE, or CSP overall jacket.

Direct current circuits which are routed aboveground, and all 120-volt AC circuits, will utilize the same construction as below grade DC circuits, as stated above, or may utilize multiple conductor control cable having 10, 12, or 14 AWG stranded copper conductors, NEC Type TC with THHN or THWN (PVC/nylon) insulated conductors, and with an FRPVC overall jacket.

The conductor size for current transformer circuits will be 10 AWG or larger.

4.2.8 Instrument Cable 600 Volt

Instrument cable will be used for control and instrument circuits that require shielding to avoid induced currents and voltages.

Cables may be routed in trays, conduits, or ducts and will be routed separate from 600-volt power circuits. The following cable constructions will be utilized:

- 600-volt, single pair and single triad shielded instrument cable, 16 AWG stranded copper conductors, XLPE or EPR insulation, FRPVC, CPE, or CSP jacket overall.
- 600-volt multiple pair, shielded instrument cable with individually shielded pairs and overall shield, 16 AWG stranded copper conductors, XLPE or EPR insulation, FRPVC, CPE, or CSP jacket overall.

4.2.9 Thermocouple Extension Cable

Thermocouple extension cable will be used for extension leads from thermocouples to junction boxes and to instruments for measurements of temperature. Cables may be routed in trays, conduits, or ducts. The following cable construction will be utilized:

- 600-volt, single pair, solid alloy conductor with the same material as the thermocouples, with shield over each pair (except for one pair construction) and with an overall shield, l6 AWG XLPE or EPR insulation; FRPVC, CPE, or CSP jacket overall.

4.2.10 High Temperature Cable

High temperature cable will be used for wiring to devices located in areas with ambient temperatures above 75°C. Cables may be routed in conduit. Cable lengths will be minimized by terminating the cable at terminal boxes or conduit outlet fittings located outside the high

temperature area and continuing the circuit with control or thermocouple extension cable. The following cable construction will be used:

- Single-conductor control cable; NEC Type SF-2 12 AWG; stranded copper conductor; silicone rubber insulation; braided glass jacket.
- Single pair shielded thermocouple extension cable; solid alloy conductor with the same material as the thermocouples; 16 AWG; FEP Teflon insulation; FEP Teflon jacket overall.

4.2.11 Lighting and Fixture Cable

Lighting and fixture cable designations and conductor sizes will be identified on the drawings. Minimum conductor size will be 12 AWG.Lighting and fixture cable with 600-volt insulation will be used as follows:

- NEC Type 600 V, 90 degrees, XHHW-2 with copper conductor for 120-volt circuits in outdoor or unheated areas or 208-volt circuits in all areas. All circuit runs totally in conduit.
- Circuit runs for roadway or outdoor area lighting enclosed in PVC duct, stranded copper conductors, NEC Type 600 V, 90 degrees, XHHW-2 conductor insulation.
- Circuit runs for interior lighting and receptacles circuits (120 volts or less) will be copper, 600 V, 75 degrees NEC Type THHN insulation or equal.
- Fixture wire, NEC Type SF-2, with copper conductor, silicone rubber insulation, braided glass jacket.

4.2.12 Grounding Cable

Grounding cable will be insulated NEC Type THW or THHN or uninsulated bare copper conductor sized as required.

4.2.13 Switchboard and Panel Cable

Switchboard and panel cable will be insulated to 600 V. Cable will be NEC Type SIS or XHHW-2, meeting the UL VW-1 flame test.

4.2.14 Special Cable

Special cable will include cable supplied with equipment, prefabricated cable, coaxial cable, communication cable, etc. This cable will normally be supplied by a particular manufacturer. Special cable will be routed in accordance with the manufacturer's recommendations.

4.2.15 Miscellaneous Cable

If other types and constructions of cable are required as design and construction of the unit progress, they will be designated and routed as required.

4.3 Testing Requirements

Preoperational testing of installed cables will be performed by the Construction Contractor on insulated conductors after installation, as follows:

Insulated conductors with insulation rated 5,000 volts and above will be given a field DC insulation test.

Low voltage cables will be either insulation-resistance tested before connecting to equipment or functionally tested (at equipment operation voltage) as part of the checkout of the equipment system.

Insulated conductors will be continuity-tested for correct conductor identification.

4.4 Installation

Cable installation will be performed by the Construction Contractor in accordance with the following general rules:

- Cables will be routed as indicated in the circuit list. Each circuit will be assigned an unique number.
- The pulling tension of cable will not exceed the maximum tension recommended by the cable manufacturer, and the sidewall pressure at a bend will not exceed the cable manufacturer's recommendations. Maximum bend radii shall not exceed the manufacturer's recommendations.
- Care will be exercised during the placement of all cable to prevent tension and bending conditions in violation of the manufacturer's recommendations.
- All cable supports and securing devices will have bearing surfaces located parallel to the surfaces of the cable sheath and will be installed to provide adequate support without deformation of the cable jackets or insulation.
- Nylon ties will be used to neatly lace together conductors entering panelboards, control panels, and similar locations after the conductors have emerged from their supporting raceway and before they are attached to terminals.
- The Electrical Construction Contractor will identify both ends of all circuits. He will also identify all circuits at manholes and handholes.
- All spare conductors of a multi-conductor cable will be left at their maximum length for possible replacement of any other conductor in the cable. Each spare conductor will be neatly coiled and taped to the conductors being used.
- In addition to the above requirements, cables will be installed in accordance with manufacturer's requirements and recommendations.

4.5 Connectors

This subsection defines methods of connecting cable between electrical systems and equipment. In this subsection, the term "connector" is applied to devices that join two or more conductors or are used to terminate conductors at equipment terminals for the purpose of providing a continuous electrical path.

Connector material will be compatible with the conductor material to avoid the occurrence of electrolytic action between metals.

All medium voltage and low voltage connectors will be pressure type and secured by using a crimping tool. The tool will be a ratchet type and a product of the connector manufacturer made for the particular connector to be installed. The tool will produce a crimp without damage to the conductor, but will assure a firm metal to metal contact.

Medium voltage cables require stress cones at the termination of the cables. Stress cones will be of the preformed type suitable for the cable to which they are to be applied.

Cables will not be spliced in cable trays or conduits. Control and low-level instrument cable will be spliced only at pigtails and at the transition to high temperature wire. Connections will be made in conduit outlet fittings or junction boxes utilizing terminal blocks or an appropriate connector.

5.0 Protective Relaying

The selection and application of protective relays is discussed in the following paragraphs. These relays protect equipment in the Auxiliary Power Supply System, Generator Terminal System, Primary Power Supply System, Turbine-Generator System, and the electrical loads powered from these systems.

The following general requirements apply to all protective relay applications:

- The protective relaying scheme will be designed to remove or alarm any of the following abnormal occurrences on equipment designed for electrical power generation, voltage transformation, energy conversion, and transmission/distribution of electrical power:
  - Overcurrent
  - Undervoltage or overvoltage
  - Frequency variations
  - Overtemperature
  - Abnormal pressure
  - Open circuits and unbalanced current
  - Abnormal direction of power flow
- The protective relaying scheme will also achieve the following:
  - Limit damage to faulted equipment
  - Minimize possibility of fire or explosion
  - Minimize hazards to personnel
- The protective relaying system will be a coordinated application of either individual relays, multifunction relays, or a combination of individual and multifunction relays. Solid-state multifunction relays will be used wherever possible. For each monitored abnormal condition, there will exist a designated primary device for detection of that condition. A failure of any primary relay will result in the action of a secondary, overlapping scheme if possible to detect the effect of the same abnormal occurrence. The secondary relay may be the primary relay for a different abnormal condition. Alternate relays may exist which detect the initial abnormal condition but which have an inherent time delay so that the alternate relays will operate after the primary and secondary relays. Similar to secondary relays, the alternate relays may be primary relays for other

abnormal conditions. All protective relays will be selected to coordinate with protective devices supplied by manufacturers of major items and the thermal limits of electrical equipment, such as transformers and motors. Where selective coordination cannot be achieved, protection will be maintained.

- Secondary current produced by current transformers will be in the 5-ampere range, and voltage signals produced by potential transformers will be in the 120-volt range.

5.1 Generator Protective Relays

Generator protective relay packages will be furnished in accordance with the particular manufacturer's requirements. Protective relaying and monitoring will be selected to provide, as a minimum, detection and correction/isolation action as required for faults and malfunctions. In general, protective relay packages, including generator differential protection, will be provided to minimize the effects from the following faults and malfunctions and will be interfaced with the utility's protection scheme:

- Generator phase faults
- Generator stator ground faults
- Stator open circuits and unbalanced currents
- Loss of excitation
- Backup protection for external system faults
- Reverse power
- Generator potential transformer circuit monitoring
- Underfrequency/overfrequency
- Breaker failure
- Inadvertent energization of the generator from the system

In general, equipment furnished with the generator's excitation equipment will provide the following additional protection:

- Underexcitation
- Overexcitation
- Generator field ground faults
- Excessive volts per hertz
- Exciter field ground faults

Additional generator protective monitoring equipment will be provided to protect against the following:

- High bearing temperatures
- Overspeed conditions
- Excessive vibrations
- Generator overheating

A typical complement of protective relays for the turbine generator may be as follows. The actual protective relaying to be used will be developed during design stages:

- **Generator Differential Relay (Device 87-G1).** A generator differential relay will provide primary generator protection against three-phase and phase-to-phase faults

within the generator. This relay will not detect ground faults within its zone of protection.

- **Generator Ground Relays (Device 64-G).** Device 64-G will be a low voltage pickup, overvoltage relay which will sense voltage across the generator neutral grounding transformer secondary resistor when a ground fault occurs in the generator, isolated phase bus duct, generator transformer low voltage windings, auxiliary transformer high voltage windings, or the surge protection and potential transformer equipment.
- **Negative Sequence Relay (Device 46).** The negative sequence relay provides protection against unbalanced phase currents, which result from unbalanced loading, unbalanced faults, a turn-to-turn winding fault, and an open circuit. Negative sequence currents exceeding the generator allowable limits result in overheating of the generator rotor.
- **Loss-of-Field Relays (Device 40).** The loss-of-field relay complete with timer will provide protection against thermal damage caused by underexcitation and loss-of-field. These relays provide backup protection for excitation system protective devices furnished with the generator.
- **Reverse Power Relays (Device 32).** Reverse power relays (Device 32) will provide protection of the turbine generator by detection of reverse power flow and motoring of the generator. Reverse power proven (Device 32) will initiate a normal sequential shutdown.
- **Voltage Balance Relays (Device 60).** Voltage balance relay (Device 60) will monitor potential transformer circuits to the generator voltage regulator and protective relays. Upon loss of relaying potential, Device 60 will disable the loss-of-field relay (Device 40) to avoid false tripping of the unit. Upon loss of potential to the voltage regulator, Relay 60 will transfer the voltage regulator from the automatic to manual mode of operation. An alarm will be actuated upon loss of either potential.
- **Underfrequency and Overfrequency Relays (Device 81).** Underfrequency and over frequency conditions will be detected by Device 81.
- **Overvoltage and Undervoltage Protection (Devices 27 and 59).** The voltage regulator and excitation system include interlocks and protective circuits to prevent operating the generator beyond its design limits. An under voltage relay (Device 27) and an overvoltage relay (Device 59) will alarm if the voltage regulator fails to maintain voltage within design limits.
- **Field Ground Fault Protection (Device 64F).** Grounds on the generator field will be alarmed by Device 64F.
- **Generator Backup Distance Relay (Device 21G).** This relay will provide backup protection against external system faults. This relay will operate only if an external system fault persists after all other primary system relays, including breaker failure, have failed to operate. This relay will trip the generator lockout relay.
- **Inadvertent Back Energization Protection (Device 50/27).** This relay will provide protection of the generator against inadvertent energization when it is at standstill, on turning gear, or coasting to a stop.

- **Breaker Failure Relay (Device 50BF). This relay will provide protection against the** generator breaker failing to open. This relay will operate when an external system fault persists after all other primary systems have failed to open the generator breaker.
- **Excessive Volts per Hertz Relay**.

5.2 Power Transformer Relays

5.2.1 Generator Step-Up Transformer

The generator transformer is protected against the effects of the following conditions:

- Phase faults
- Ground faults
- Sudden pressure
- Excessive tank pressure
- Combustible gas
- Oil level
- High temperature
- Excessive volts per hertz (protection from the volts per hertz relay used with the generator)

This protection will be provided by the relays, which are discussed in the following paragraphs.

Device 87-T1 is a differential relay that provides transformer primary protection by detection of three-phase and phase-to-phase faults in the generator transformer low voltage delta-connected windings, and three-phase, phase-to-phase, and phase-to-ground faults in the generator transformer high voltage wye-connected windings.

Device 51-TN will provide sensitive backup protection for ground faults in the external system.

A rapid increase in pressure within the transformer tank associated with an internal fault will be detected by a sudden-pressure relay, Device 63-T1. This relay will be furnished with the transformer.

Loss of cooling and resulting high temperature will be alarmed.

5.2.2 Auxiliary Transformer

The auxiliary transformer is protected against the effects of the following conditions:

- Phase faults
- Ground faults
- Sudden pressure

This protection will be provided by the following relays, which are discussed in the following paragraphs.

Device 87 provides primary protection for the high voltage and low voltage windings of the auxiliary transformers and for the cable connecting each low voltage winding to each incoming main breaker in the plant metal-clad switchgear lineups. These relays offer

protection against phase-to-phase and three-phase faults. Device 87 is relatively insensitive to ground faults on the secondary side of the transformer should the fault current magnitudes be less than the maximum available ground fault current.

One time over current relay (Device 51/N) is connected to the bushing current transformer on the neutral of the low voltage winding of the auxiliary transformer. This relay provides primary overload protection to its neutral winding's resistor for ground faults on the switchgear buses or on feeders emanating from the switchgear lineups. This relay also provides backup protection for ground faults in the transformer low voltage winding, in the cable, on the switchgear buses, or on feeders emanating from the switchgear lineups.

A rapid increase in pressure within the transformer tank associated with an internal fault will be detected by a sudden-pressure relay, Device 63. This relay will be furnished with the transformer. Loss of cooling and resulting high temperature will be alarmed.

5.3 Metal-Clad Switchgear

The protective relays used in the 4,160-volt metal-clad switchgear lineups are discussed in the following paragraphs. The relays for the auxiliary electrical protective relay system will be selected and set to provide coordinated tripping to mitigate the faulted connection.

5.3.1 Bus and Incoming (Source) Breakers and/or Medium Voltage Contactors

Each incoming (source) breaker and contactor will be provided wit protective relay type devices. These devices may be single element type or multifunction relays. The incoming breakers and/or contactors and bus will be provided with devices to detect and take appropriate action against the effects of the following conditions:

- Phase faults
- Ground faults
- Overloads
- Undervoltage

In general, each breaker will have time over current relays (Device 51) and a time over current ground detection relay (Device 51N). Device 51 will detect and trip the respective switchgear incoming breaker for sustained overloads and short-circuit currents on the switchgear bus. These relays will provide backup protection for faults on feeders emanating from the switchgear lineups. Device 51N will be residually connected to switchgear current transformers and provide primary protection for ground faults on the switchgear bus and backup protection for ground faults in feeders emanating from the switchgear lineup.

Each medium voltage switchgear bus will be provided with two under voltage relays (Device 27) or transducers which will, when bus voltage drops to a preset level, trip load feeder circuits.

5.3.2 Secondary Unit Substation Feeders

Each secondary unit substation transformer will be protected by 4.16 kV NEMA type fused motor starter contactor assembly and a Multilin solid-state multifunction protective relay. The Multilin will provide primary equipment and cable time over current, instantaneous over current, open phase, ground, and zero sequence protection. Both the longtime and instantaneous elements for phase protection will be adjustable.

5.3.3 Motor Feeders

Each single speed induction motor feeder will be protected by 4.16 kV NEMA type fused motor starter contactor assembly and a Multilin solid-state multifunction protective relay. The Multilin protective relay will provide primary equipment and cable time phase/ground time overcurrent (51/51N), phase/ground overcurrent (50/50N), and negative sequence (46) protection.

5.3.4 480 Volt Secondary Unit Substation Switchgear

Overload and fault protection for loads connected to the 480-volt secondary unit substations (SUS) will be provided by solid-state trip devices (SSTDs), which are an integral part of drawout air circuit breakers.

Breakers supplying motors or other devices that do not require coordination with downstream trip devices will have adjustable long-time and instantaneous elements for phase protection and will include ground fault protection.

Main breakers, tie breakers and breakers supplying motor control centers (MCCs) or other loads that contain trip devices will have adjustable long-time and short-time SSTD elements for phase protection and will include ground fault protection. The pickup point and time settings will be adjustable to allow for proper coordination with all downstream trip devices.

Sustained under voltage in the 480-volt secondary unit substation switchgear bus will be detected by under voltage relays (Device 27) or transducers.

5.3.5 480 Volt Motor Control Centers

MCCs will be protected by the 480-V switchgear feeder breakers, which have adjustable long-time and short-time SSTD elements for phase protection and ground fault protection in a manner similar to that described in Subsection 2-4.3.3.4, 480-Volt Secondary Unit Substation Switchgear. The SSTD will protect the MCC feeder circuit and the bus against sustained short-circuit currents and serve as backup protection for MCC feeder circuits.

Each magnetic starter within an MCC that supplies power to a motor will have a magnetic-only molded case circuit breaker with adjustable motor circuit protector and a thermal overload element in the starter.

Certain nonmotor loads will be fed from MCC feeder circuit breakers. The feeder breakers will be thermal-magnetic molded-case breakers sized to protect supply cable and individual loads.

5.3.6 480-Volt Power Panels

Power panels will have thermal-magnetic circuit breakers sized to protect supply cable and individual loads.

6.0 Classification of Hazardous Area

Areas where flammable and combustible liquids, gases, and dusts are handled and stored will be classified for the purpose of determining the minimum criteria for design and installation of electrical equipment to minimize the possibility of ignition. The criteria for

determining the appropriate classification are specified in National Electrical Code (NEC) Article 500 (NFPA 70/ANSI C1). The application of these criteria to specific areas at generating stations is provided in Article 127 of the National Electrical Safety Code (NESC/ANSI C2).

In addition to defining hazardous areas by class and division, each hazardous element is also assigned a group classification (A, B, C, etc.). The group classifications of hazardous elements are specified in NEC Article 500 and NFPA Standard 497M.

Electrical equipment in areas classified as hazardous will be constructed and installed in accordance with NEC Articles 501 and 502.

References for use in classification of areas, as well as specification of requirements for electrical installation in such areas, include:

- NESC, ANSI C2
- NEC, ANSI C1, NFPA 70/ANSI C1
- NFC, NFPA
- American Petroleum Institute Recommended Practices
- American Gas Association, Publication XFO277

6.1 Flammable and Combustible Liquid Storage and Handling

Areas where flammable and combustible liquids are stored and handled will be classified as indicated in the following subsections.

6.1.1 Flammable Liquids

Flammable liquids (flash point below 100°F/38°C), which include gasoline (Group D hazard), will be considered hazardous wherever they are handled or stored. The areas where gasoline is handled or stored will be classified as specified in Section 127.E of the National Electrical Safety Code.

6.1.2 Combustible Liquids

Combustible liquids (flash point of 100°F/38°C or higher) include fuel oil, diesel fuel, and lubrication oil (Group D hazards). Areas where these liquids are handled or stored will not be classified because they will not be handled or stored at temperatures which will produce sufficient vapors to form an ignitable mixture with air beyond the surface of the liquid within the piping or vessel in which they are normally contained.

6.2 Gaseous Hydrogen Systems

(Not Applicable).

6.3 Natural Gas Systems

Natural gas systems used as a fuel source for combustion turbine generators will be classified as follows. Classification of areas within the combustion turbine equipment is as follows:

- Outdoor areas within 5 feet (1.5 m) of vents from relief valves will be Class I, Division 1, Group D. The area from 5 feet (1.5 m) to 15 feet (4.5 m) from the vent will be classified as Class I, Division 2, Group D.

- Enclosed areas which are adequately ventilated and contain equipment such as gas compressors, valves, regulators, etc., where natural gas will be present outside of the contained equipment only upon equipment failure will be classified Class I, Division 2, Group D. An area extending 5 feet (1.5 m) from the ridge vents for such enclosures shall also be classified Class I, Division 2, Group D.
- Outdoor areas within 15 feet (4.5 m) of gas compressors, regulators, valves, etc., will be classified Class I, Division 2, Group D.
- Enclosed areas which are not adequately ventilated and where bleed gas or gas leakage is anticipated will be classified Class I, Division 1, Group D. Adequately ventilated areas within 10 feet (3 m) of these enclosures, unless separated by a vapor tight barrier, will be classified as Class I, Division 2, Group D. Areas separated by a vapor tight barrier will be classified as nonhazardous.
- Enclosed areas which are adequately ventilated and contain equipment such as valves, pipe flanges, instruments, screwed pipe connections, etc., where natural gas will be present outside of the contained equipment only upon equipment failure, and which contain natural gas detectors which shut off the supply of natural gas outside the enclosed area, will be classified as nonhazardous except for within 15 feet (4.5 m) of the valve, flange, instrument, or screwed connection (potential source of gas), which shall be classified as Class I, Division 2, Group D.
- Indoor areas such as burner fronts where flames, heat, or other such sources of ignition are present will not be classified as hazardous.
- The use of low-pressure natural gas for building heating systems will not in itself be considered a cause for classifying an adequately ventilated area as hazardous.

6.4 Liquid Hydrogen Systems

(Not Applicable).

6.5 Sewage Lift Stations

Sewage lift station wet wells and any enclosed nonventilated area above the wet well will be classified Class I, Division 1, Group D.

7.0 Grounding

The station grounding system will be in an interconnected network of bare copper conductor and copper-clad ground rods. The system will protect plant personnel and equipment from the hazards that can occur during power system faults and lightning strikes.

7.1 Design Basis

The station grounding grid will be designed for adequate capacity to dissipate heat from ground current under the most severe conditions in areas of high ground fault current concentrations, with grid spacing such that safe voltage gradients are maintained.

Bare conductors to be installed below grade will be spaced in a grid pattern to be indicated on the construction drawings prepared during detailed design. Each junction of the grid will be bonded together by an exothermal welding process.

In plant areas, grounding stingers will be brought through the ground floor and connected to the building steel and selected equipment. Concrete floor penetrations will be through PVC conduit embedded in the concrete. The grounding system will be extended, by way of stingers and conductor installed in cable tray, to the remaining plant equipment. Equipment grounds will conform to the following general guidelines:

- Grounds will conform to the NEC and NESC.
- Major items of equipment, such as switchgear, secondary unit substations, motor control centers, relay panels, and control panels, will have integral ground buses which will be connected to the station ground grid.
- Electronic panels and equipment, where required, will be grounded utilizing an insulated ground wire connected in accordance with the manufacturer's recommendations. Where practical, electronics ground loops will be avoided. Where this is not practical, isolation transformers will be furnished.
- Distributed control system (DCS) cabinets and equipment will be grounded according to manufacturer's requirements or recommendations.
- Motor supply circuits to 460 volt motors, which utilize three-conductor cable with a ground in the interstices, will utilize this ground for the motor ground. For 460 volt motor supply circuits, which utilize three single-conductor cables, a separate ground conductor will be utilized. The separate ground conductor will be sized in accordance with applicable codes.
- All 4,160 volt motors will have a minimum of one 1/0 AWG bare copper ground conductor connected between the motor frame and the station ground grid.
- All large mechanical equipment such as tanks, pressure vessels, skids, etc. will have a minimum of two 1/0 AWG bare copper ground conductors, located at diagonally opposite corners, connected from the equipment ground pad or frame, to the station ground grid.
- All ground wires installed in conduit will be insulated.

Remote buildings and outlying areas with electrical equipment will be grounded by establishing local subgrade ground grids and equipment grounding systems in a manner similar to the plant area. Remote grids, where practical, will be interconnected with the station ground grid to reduce the hazard of transferring large fault potentials to the remote area through interconnecting instrumentation and communication cable shields.

7.2 Materials

Grounding materials furnished are described in the following:

- Rods will be copper-clad. Ground rod length and diameter will be determined by soil resistivity and subsurface mechanical properties. Where required ground rod length exceeds 10 feet, standard sections will be exothermally welded together using a guide clamp.
- Cable will be soft-drawn copper with Class B stranding or copper-clad steel.
- Exothermal welds will use molds, cartridges, and materials as manufactured by Cadweld or equivalent.
- Clamps, connectors, and other hardware used with the grounding system will be made of copper and purchased from an approved supplier.
- Ground wires installed in conduit will be soft-drawn copper with Class B stranding, and green colored 600 volt PVC insulation.

8.0 Lighting

The lighting system will provide personnel with illumination to perform indoor operation and maintenance activities, general yard task, safety, and plant security operations.

Voltage used to supply indoor and outdoor lighting fixtures will be 120, 208 volts or 277 volts single phase. The power supply for the lighting system will be from 208/120 volt and 480/277 volt, 3-phase, four-wire panelboards located within the balance of plant areas.

8.1 Light Sources

The lighting system will be designed to provide illumination levels recommended by the following standards and organizations:

- IES RP - Standard Practice for Industrial Lighting.
- IES RP - Standard Practice for Roadway Lighting.
- IES RP - Standard Practice for Lighting Offices Containing Computer Display Terminals.

Light source size and fixture selections will be based on the applicability of the luminaries for the area under consideration during detail design. Generally, high pressure sodium luminaries will be used outdoors and fluorescent luminaries will be used indoors within conditioned spaces. High pressure sodium or similar luminary may be used in high bay applications. Other special luminaries will be selected as based upon the hazardous area classification, unique applications or other specific areas to be illuminated.

For design purposes, lighting is categorized by the following areas:

- Outdoor areas.
- Roadway, area parking and security fencing.
- Indoor areas.

Table 8-1 summarizes the illumination levels.

TABLE 8-1
Illumination Levels

Location	Maintained Foot-Candles	Illumination LUX
Outdoor Catwalks and Platforms	2	20
Roadway		
Between or along buildings	1	10
Not bordered by buildings	0.5	5

8.2 Roadway and Area

Roadway and area lighting will be designed using high-pressure sodium light sources. The light fixtures will be the cutoff type designed to control and direct light within the property line of the facilities. Roadway light fixtures will be installed on hot-dip galvanized steel poles. Local task lighting will be installed on buildings or equipment.

8.3 Outdoor Areas

This category includes lighting of equipment located outdoors and outdoor platforms. High pressure sodium light sources will be used.

8.4 Indoor Areas

Indoor lighting will consist of fluorescent luminaries within office, equipment rooms and other conditioned spaces. High bay high pressure sodium luminaries will be used in larger open areas.

8.5 Lighting Control

Electric power to outdoor light fixtures will be switched on and off with photoelectric controllers. Local task lighting will be controlled with photoelectric controllers and manual switches at the task.

8.6 Wiring Devices

Convenience outlets located outdoors will be provided with weatherproof snap-action covers. In hazardous locations, convenience outlets will be suitable for the NEC class and group requirements.

9.0 Freeze Protection

Piping subject to freezing will be protected with electric heating cable.

9.1 Above Grade Freeze Protected Piping

The electric heating cable will be applied directly to the pipeline, and insulation shall be applied over the pipe and cable. The insulation shall be mineral fiber or fiberglass insulation. Class F insulation shall be used on all piping to be freeze protected for which an insulation class is not specified. Mineral fiber preformed pipe insulation for this application shall have a nominal density of 8 to 10 pounds per cubic foot (128 to 160 kg per cubic meter). Fiberglass

blanket shall have a minimum nominal density of 3.5 pounds per cubic foot (56 kg per cubic meter). When the contract includes insulation materials for freeze protected pipe, aluminum foil wrap shall be provided for a single wrap of foil over the heat tracing cable.

Heat tracing on exterior aboveground freeze protected pipelines will extend down to the frost line regardless of the piping classification for the below grade portion of the pipeline.

The electric heating cable will be tested prior to being covered with insulation. After all insulation and jacketing have been installed, the heating cable will again be tested. If the cable is found to be damaged, the Supplier shall remove the jacketing and insulation to allow for inspection of the cable. If the electric heating cable was installed by others and if, in the opinion of the Purchaser, the damage to the cable was done during the insulation and jacketing work, the Supplier shall be responsible for all costs involved in replacing the cable including cost of the cable, its installation and testing, and the additional insulation and jacketing work. The Supplier will be reimbursed for the extra work if the damage did not result from his operation.

9.2 Below Grade Freeze Protected Piping

Outdoor above grade piping that is freeze protected and continues below grade will have the heat tracing extended to the frost line. Water resistant type insulation shall be installed below grade for this application. The insulation shall be held in place using aluminum lagging and end cap. All seams shall be sealed.

9.3 Vessels, Tanks, and Pump Casings

Tanks or vessels subject to freezing will be protected by auxiliary steam, electric immersion type heaters, electric panels or pads, or heat trace cables. Heat trace cable, if selected, will be applied in a serpentine or spiral manner, covering the bottom half of tanks 20 feet tall and shorter, and covering the bottom third of tanks taller than 20 feet.

10.0 Lightning Protection

Lightning protection will be provided as required for stacks and top of tall buildings.

Lightning protection for stacks will consist of air terminals provided at radial intervals around the top of the stack. The air terminals will be connected together by copper cable and connected to the plant ground grid with not less than two copper down conductors. Protection against side strokes will be considered for obstruction lighting, antennas, and external elevators.

Lightning protection for tall buildings will consist of air terminals installed on the roof. The air terminals will be connected together with copper cable and connected to the plant ground grid with copper down conductors. Air terminals will be arranged to provide protection for roof penetrating devices, such as piping, air moving equipment, etc.

11.0 Raceway and Conduit

The design and specifications for the raceway and conduit systems used in supporting and protecting electrical cable will be in accordance with the provisions of the NEC.

11.1 Cable Tray

All cable trays except electronic trays will be of trough or ladder type construction with a maximum rung spacing of 6 inches, nominal depths of 4 to 6 inches, and various widths as required. There will be a maximum spacing of 8 feet between cable tray supports, except fittings (elbows, tees, etc.) which shall be supported in accordance with standards.

Cable tray fittings will have a radius equal to or greater than the minimum bending radius of the cables they contain.

Solid bottom trays will be provided for all electric systems such as special noise-sensitive circuits and analog instrumentation circuits.

Individual tray systems will be established for the following services:

- Medium voltage power cables.
- 600-volt power cables equal to or greater than 2/0 AWG.
- 120-volt AC and 125-volt DC power, control, and multi-conductor 600-volt power
- Special noise-sensitive circuits or instrumentation cables.

Further division will be provided where required by the equipment manufacturer.

The summation of the cross-sectional areas of cable in tray will be limited to 30 percent of the usable cross section of the tray for medium voltage power cables and to 40 percent for 600-volt power and control cables and electronic cables.

The minimum design vertical spacing for trays will be 12 inches measured from the bottom of the upper tray to the top of the lower tray. At least a 9-inch clearance will be maintained between the top of a tray and beams, piping, or other obstacles to facilitate installation of cables in the tray. A working space of not less than 24 inches will be maintained on at least one side of each tray.

Ventilated covers will be provided for vertical trays. Solid covers will be provided for all solid bottom tray and for all outdoor tray. Solid covers will also be provided for the top tray of horizontal tray runs located under grating floor or insulated piping.

11.2 Conduit

Conduit will be used to protect conductors routed to individual devices, in hazardous areas, and where the quantity of cable does not economically justify the use of cable tray.

Electrical Metallic Tubing (EMT) will be used indoors in nonhazardous areas for lighting branch circuits and communication circuits.

Polyvinyl chloride conduit will be used for underground duct banks and some below grade concrete encased conduit.

Liquid tight flexible metallic conduit will be used for connections to accessory devices such as: solenoid valves, limit switches, pressure switches, etc.; for connections to motors or other vibrating equipment; and across areas where expansion or movement of the conduit is required.

All other conduit, unless specific environmental requirements dictate the use of plastic or aluminum conduit, will be rigid galvanized steel.

Exposed conduit will be routed parallel or perpendicular to dominant surfaces with right angle turns made of symmetrical conduit bends or fittings.

Conduit will be routed at least 6 inches from the insulated surfaces of hot water, steam pipes, and other hot surfaces.

Conduit will be sized in accordance with the conduit fill requirements of the National Electrical Code.

Conduit will be securely supported within 3 feet of connections to boxes and cabinets.

Conduit larger than one-half inch and up to 1.25 inches will be supported by supports with a maximum separation of 8 feet. Conduit 1.5 inch and larger will be supported by supports located at least every 10 feet.

11.3 Duct Bank and Manholes

Underground duct banks will be used for cable routed between outlying areas and other remote areas as necessary.

All underground duct banks will consist of Type EB PVC tubing encased in reinforced concrete. The nominal diameter of the plastic ducts will be 4 inches. A 3 inch or larger galvanized steel conduit will also be installed where required for analog low-level circuits requiring noise immunity from adjacent power circuits.

All underground duct banks will be installed in accordance with the following methods:

- Ducts will be sloped not less than 3 inches per 100 feet to manholes to provide adequate drainage. Low spots in duct runs will be avoided.
- Reinforcing steel will not form closed magnetic paths between ducts. Nonmetallic spacers will be used to maintain duct spacing.

Reinforced concrete manholes and electrical vaults will be provided, where required, so that cable may be installed without exceeding allowable pulling tensions and cable sidewall pressures. Each manhole will have the following provisions:

- Provisions for attachment of cable pulling devices
- Provisions for racking of cables
- Manhole covers of sufficient size to loop feed the largest diameter cable through the manhole without splicing
- Sealed bottoms and sumps
- Water stops at duct bank entrances

Duct bank risers and conduit from manholes to the equipment at remote locations will be changed to rigid steel prior to emerging from below grade. All below grade steel conduit will be wrapped and encased in concrete.

Duct banks and manholes shall be designed in accordance with the seismic criteria defined in the Structural and Seismic Engineering Design Criteria.

Duct banks will be designed to include spare capacity after completion of installation to allow for future growth and expansion.

12.0 Battery System

The batteries used for the DC power supply system for the balance-of-plant loads will consist of 125-volt pressure regulated type batteries.