Appendix B

Design Criteria – Engineering/Construction Specifications

Appendix B-1

Civil Engineering

APPENDIX B1
CIVIL ENGINEERING DESIGN CRITERIA
TABLE OF CONTENTS

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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 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
- Preliminary and detailed design
- Procurement
- Construction and construction management
- Startup, testing, and checkout
- Project completion

The purpose of this appendix is to summarize the codes, standards and practices that will be used for the Project. The general Civil Engineering Design Criteria defined herein will form the basis of the design for the Project Site preparation, Project Site drainage, roads and other civil systems for the Project. More specific design requirements will be developed during preliminary and detailed design to support material procurement and construction. 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 engineering criteria that will be used for design.

Section 2.0 summarizes the applicable codes, standards, laws and ordinances and Section 3.0 provides general criteria for civil works.

2.0 APPLICABLE LAWS, ORDINANCES, REGULATIONS, AND STANDARDS

The design and construction of the facility will conform to the following laws, ordinances, regulations, and standards (LORS). When an edition date is not indicated, the latest edition and addenda applicable at start of detailed design will apply.

2.1 Federal

- Title 29, Code of Federal Regulations (CFR), Part 1910, Occupational Safety and Health Standards.
- Title 40, CFR §112 et seq., U.S. Environmental Protection Agency (EPA), Oil Pollution Prevention requires a Spill Prevention Control and Countermeasure (SPCC) plan of facilities storing oil in excess of 1,320 gallons in aggregate in above-ground containers 55 gallons or greater in capacity; or 42,000 gallons total storage below ground.

2.2 State

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

- California Vehicle Code § 35780, et seq., requires a land permit from Caltrans to transport heavy loads on state roads.
- California Labor Code § 6500, et seq., requires a permit for construction of trenches or excavations 5 feet or deeper where personnel have to descend. This also applies to construction of any building; structure, false work or scaffolding which is more than three stories high or equivalent.
- State of California Department of Transportation (Caltrans), Standard Specifications.
- Title 24, Code of California Regulations (CCR) § 2-111, et seq.; § 3-100, et seq.; § 4-106, et seq.; § 5-102, et seq.; § 6-T8-769, et seq.; § 6-T8-3233, et seq.; §6-T8-3270, et seq.; § 6-T8-5138, et seq.; § 6T8-5465, et seq.; §6-T8-5531, et seq.; and §6-T8-5545, et seq.
- Title 8, Code of California Regulations (CCR), §1500, et seq.; §2300, et seq.; and §3200, et seq., describes general construction safety orders, industrial safety orders, and work safety requirements and procedures.

2.3 County

- Kern County Code, Title 17 Buildings And Construction, Chapter 17.28 Grading Code.

2.4 Industry Codes and Standards

The following industry codes and standards will be followed in development of project specifications and design guidelines.

- Specifications for materials will generally follow the standard specification for the American Society for Testing and Materials (ASTM) and the American National Standards Institute (ANSI).
- Field and laboratory testing procedures for materials will follow standard ASTM specifications.
- Design and placement of structural concrete will follow the recommended practices and the latest version of the American Concrete Institute Code (ACI) and the Concrete Reinforcing Steel Institute (CRSI).
- Welding procedures and qualifications for welders will follow the recommended practices and codes of the American Welding Society (AWS).
- Preparation of metal surfaces for coating systems will follow the specifications and standard practices of the Steel Structures Painting Council (SSPC), National Association for Corrosion Engineers (NACE) and the specific instructions of the coatings manufacturer.
- Plumbing will conform to the International Plumbing Code (IPC), 2006 Edition.
- American Association of State Highway and Transportation Officials (AASHTO), Bridge Design Specifications, 4th edition, 2008 Interim Revisions.
- American Water Works Association (AWWA).

3.0 CIVIL DESIGN CRITERIA

3.1 Foundations

3.1.1 Geotechnical Investigation

A preliminary geotechnical investigation has been performed by URS (Job No. 22239758) and the report is included in Appendix P as part of this submittal. A detailed geotechnical investigation will be conducted during subsequent engineering phase.

The Project Site existing surface elevations vary from about 445 feet in the south-west corner to about 310 feet in the north-east corner above mean sea level (msl). The subsurface soils generally consist of silty sands to the explored depth of 90 feet. The upper 10 feet is observed to loose granular alluvial soils. Ground water is below 70 feet from existing surface. The onsite sandy soils are suitable for engineered fill.

3.1.2 Foundation Design criteria

The preliminary Geotechnical Investigation Report has identified the use of shallow foundations or deep (pile) foundations. Detailed foundation design criteria, including allowable soil bearing pressures, piling and dynamic soil properties will be developed for the project based on the results and recommendations contained in the of the detailed geotechnical investigation report.

3.2 Design Loads

Design loads for structures and equipment foundations are discussed in Appendix B-2, Structural Design Criteria. Design loads for pavements and buried items will be determined according to the criteria described below.

3.2.1 Vehicular Loads

Plant roads, process area concrete pavements, buried piping, box culverts, and embankments will be designed for AASHTO HS-20 truckload. Loads for construction equipment such as loaded scrapers, crawler cranes, equipment transport trailers, etc., may exceed the more typical HS-20 loadings and such loadings will be evaluated based on equipment manufacturer's loading recommendations.

3.3 Project Site

3.3.1 Project Site Arrangement

The Project Site arrangement will conform to applicable laws, regulations, and environmental standards. The principle elements in the selection of Project Site arrangement criteria are the physical space requirements and relationships dictated by each of the major plant systems. Distances between various systems will be minimized for economy. However, adequate clearance between various systems will be provided as needed for construction, operations, maintenance, and fire protection. The plant will be located and oriented to minimize costs of construction, while remaining operationally efficient. Utility interconnections will be optimized as much as practical. Treatment systems will be provided for facility wastewater streams. A sanitary wastewater disposal system will be provided.

The Project Site arrangement will be developed to optimize fill and/or excavation costs while maintaining the safety and efficiency of plant construction, operation, and maintenance. Internal access roads will be provided within the plant for construction and operation purposes. Drainage area inlets will collect surface runoff. Inlets will connect to the storm drainage system that discharges to a zero discharge stormwater retention basin.

The following criteria will be followed regarding Project Site infrastructure:

- Surfaces will be graded to drain.
- Roads will be designed for ease of construction and operational access.
- Oil and chemical storage areas will be designed to contain spills.
- Culverts and storm drain systems will be installed.
- Sanitary sewer collection and onsite disposal system will be installed.
- Location and requirements for fencing or walls will conform to local laws and regulations.

3.3.2 Project Site Survey Control

A topographic mapping survey was completed for Section 22, Township 30 South, Range 24 East, Mount Diablo Principal Meridian, Kern County, California dated January 19, 2008. The Project Site is located in the north half of Section 22. The basis for horizontal control is the California Coordinate System (CCS 83) Zone V, 2007.0 Epoch, relative to the North American Datum of 1983 (NAD 83). The basis of bearings for the Project Site is tied to National Geodetic Survey (NGS) continuous operating reference stations BVPP and P563. The vertical datum is the North American Vertical Datum of 1988 (NAVD 88). A Record of Survey for the Project Site is on file with the Kern County Surveyor's office.

3.3.3 Project Site Preparation

Project Site preparation will consist of clearing, stripping and grubbing and the excavation or filling of soils to design grades and elevations. Cut and fill slopes and embankments will be designed to be stable and capable of carrying anticipated loads from either equipment or structures. Root mats or stumps, if any, will be removed. Holes will be filled with material suitable for embankment and compacted to the required density. Materials from clearing, stripping and grubbing operations containing deleterious materials will be removed from the Project Site. Topsoil, where present, will be stockpiled at a designated onsite location for future landscaping purposes.

3.3.4 Excavation and Fill

Excavation will consist of the removal of soil material to the lines and grades necessary for construction. Material suitable for backfill will be stored in stockpiles at designated locations using proper erosion protection measures. Excavated material that meets the design requirements will be used as general site fill. The volume of excavation and fill will be balanced to the maximum extent practical.

Confined temporary excavations for trenching for underground utilities installations and foundations construction will be sloped or braced to prevent cave-ins during construction. All excavation and trenching operations will comply with local, state, and federal OSHA regulations.

3.3.5 Grading and Embankments

Graded areas will be smooth, compacted, free from irregular surface changes, and sloped to drain.

Final earth grades adjacent to buildings will be at least 6 inches below finished floor surface elevation and will be sloped away from the building to maintain proper drainage.

Slopes for permanent embankments will be no steeper than 2:1 (horizontal to vertical) as recommended in the geotechnical report.

3.3.6 Backfilling and Compaction

Areas to receive fill will be prepared by removing unsuitable material and rocks. The bottom of the excavation will be examined for loose or soft materials. Such materials will be excavated fully and backfilled with compacted fill material. Fill material will be placed and compacted to the grades and densities recommended in the detailed geotechnical investigation report.

Backfilling will be done in layers of uniform, specified thickness. Soil in each layer will be properly moistened to facilitate compaction to achieve the specified density. In order to verify compaction, representative field density and moisture-content tests will be taken during compaction.

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

Uncompacted topsoil will be placed in areas that are to be seeded or otherwise landscaped.

3.3.7 Project Site Drainage

The Project Site drainage system will be designed to comply with all applicable federal, state, and local regulations. Project Site grading operations will establish a working surface for construction and plant operating areas, provide positive drainage from buildings and structures, and provide adequate soil coverage for the protection of underground utilities.

The drainage system in each process area is dependent on whether process solids (e.g. coal, petroleum coke, fluxant, or gasifier solids) are present. Drainage within process areas where process solids are present will be collected and conveyed through concrete-lined channels to the solids handling water collection facility, where most of the solids will settle out. The water collected by this facility will be reused as makeup to the gasification system.

Drainage within process areas where process solids are not present will be collected through a network of catch basins and conveyed through underground piping to a low flow control structure. The low flow control structure will connect to a trunk storm water interceptor channel and a low flow collection system. Runoff up to the 0.2 inches per hour rainfall will be directed to the "low flow" collection system for testing and treating (if required) prior to reuse as makeup to the cooling towers or gasification system. Runoff in excess of this rainfall (from rain events exceeding 0.2 inches per hour) will be directed to storm water retention.

Drainage outside of process unit areas but within the main plant area will be accomplished through sheet flow wherever practical. The surface drainage system will consist of mild slopes and drainage ditches. The graded surfaces will slope away from building structures at a minimum grade of 2 percent. A storm water system with inlets and underground piping will be provided in areas where swales are not feasible.

Runoff from undisturbed areas within the Project Site will sheet flow to the nearest storm interceptor drain. These drains will be designed to convey excess surface runoff to the storm water retention facility and will consist of drainage swales, culverts and/or underground piping where necessary.

Surface runoff from offsite will be intercepted at the Project Site boundaries and will be redirected around the project to perpetuate the present drainage patterns. Existing drainage courses will be improved where necessary to prevent damage to the Project from offsite runoff.

Building and equipment elevations will be located above the 100-year flood level.

Runoff from possible oil and chemical use areas, such as transformer areas and chemical storage areas, will be contained. Storm water contained in process areas will be tested and if contaminated will be disposed of in accordance with all applicable LORS. If the storm water is not contaminated, it will be directed to storm water retention.

3.3.7.1 Drainage Swales and Interceptor Channel

Drainage swales in unpaved areas of the process units will be sized to convey the 10-year rainfall runoff flow and will drain to catch basins connecting to the storm water system.

Storm water interceptor channels used to intercept runoff from the Project's undisturbed areas and from off-site will be sized to convey runoff from the 50-year rainfall event.

Erosion protection for swales and channels will be provided where peak runoff velocities will be greater than 4 feet per second (fps). These swales and channels will be protected by erosion control fabric, riprap, or concrete paving.

3.3.7.2 Drainage Culverts

Drainage culverts will be provided at road and embankment crossings. Culverts will be constructed of reinforced concrete, corrugated HDPE pipe or corrugated metal pipe. Reinforced concrete box culverts will be provided where necessary. Culverts will be sized to convey the 25-year storm event without the headwater overtopping the base of the road or top of embankment.

The minimum cover requirement of culverts will be 12 inches. All culverts will be designed to handle AASHTO HS20 truck loads and construction equipment loadings as applicable to the design. Allowance for corrosion protection over the expected life of the plant will be accounted for in the design and selection of culvert materials. Culverts will have flared end sections compatible with the ditch side slopes or concrete headwalls at both the inlet and outlet. The inlets and outlets of all culverts will be protected from erosion by the installation of riprap.

3.3.7.3 Process Unit Area Storm Water System

The storm water system within the process units will be sized to convey surface runoff from the 10-year rainfall event or fire flow, whichever is greater. Catch basins will be constructed of cast-in-place or precast concrete and secured with steel grates. Drainage pipes will be sized to limit flow velocities to a maximum of 8 fps. A minimum design velocity of 2 fps will be used to facilitate self cleaning. The minimum cover requirement, loading, and material selection for pipes will be as specified for culverts.

3.3.7.4 Storm Water Retention

Storm water retention will be sized to retain runoff from the 50 year, 24 hour storm. The retention basin will be a lined earth excavated structure. Water that accumulates in the storm water retention basin will be treated and reused as cooling water make-up, gasification water makeup or gasification water makeup.

3.3.7.5 Solids Handling Water Collection

The solids handling water collection system will capture runoff (stormwater and washdown water) from solids handling areas, which include gasification, gasifier solids temporary storage, and inactive feedstock storage. The collection facility will be constructed of concrete, and will provide for mobile equipment access to remove accumulated solids. Water that accumulates within the solids handling collection facility will be reused as makeup to gasification.

3.3.8 Erosion and Sedimentation Control

Erosion and sedimentation control measures will be provided throughout the Project Site to retain sediment onsite. In addition, the Project Site drainage system will drain to a zero discharge retention basin that will settle any remaining sediment carried by site runoff to prevent the release of sediment from the Project Site. The proposed Project Site development will alter the site topography. Vegetation will be removed as required during site clearing and grubbing operations. Preparation of the Project Site will be followed by earthmoving. Final finish grading will begin when all other earthmoving operations are completed. Final grading may include seeding disturbed areas not occupied by plant facilities or surfaced with concrete, asphalt or crushed aggregate.

Temporary erosion and sedimentation control measures to be used during construction will be designed to prevent sediments from being displaced by storm water runoff.

Along the upstream perimeter of the Project Site, temporary ditches and/or berms will be constructed as necessary to redirect runoff around the Project Site. Temporary control measures (consistent with applicable best management practices) will be maintained as necessary throughout the construction period. Temporary erosion control measures will be maintained as necessary throughout the construction period and will be designed to convey runoff from the 10-year storm event.

Permanent erosion and sedimentation control measures within the Project Site will include the runoff collection system (ditches, inlets, culverts, drainage piping) and stormwater retention basin, surfaced traffic and work areas.

3.3.9 Roads

All plant roads will be appropriately maintained during the construction period. Unsurfaced roads will receive periodic watering or applications of a dust preventive material to minimize dust problems. Vehicular traffic into and out of the Project Site will be limited as much as practical to daylight hours of the construction work days. Roads will be designed to be above the 25-year flood level.

3.3.10 Fencing and Security

Chain link security fencing will be provided around the plant 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.

3.3.11 Landscape Plan

Landscaping will be planned as follows and in consultation with the responsible public agencies:

- The landscape plan will rely on site topography, concentrating on those viewpoints visible to the general public.
- All landscape material used will be selected with due consideration for the climatic and soil conditions on the Project Site. The theme for the planting plan will be derived from an assessment of naturally occurring plant materials and an evaluation of the need for dense, hardy screening.

3.3.12 Sanitary Waste System

The sanitary waste will be discharged to an onsite sewage disposal system (leachfield). The design will be in accordance with applicable local and state codes, regulations and International Plumbing Code. The total quantity of flow used in sizing the sanitary waste system will be calculated based on the total equivalent fixture units provided. Pipe will be sloped in accordance with the International Plumbing Code.

Appendix B-2

Structural Engineering

APPENDIX B2
STRUCTURAL ENGINEERING DESIGN CRITERIA
TABLE OF CONTENTS

APPENDIX B2
STRUCTURAL ENGINEERING DESIGN CRITERIA
TABLE OF CONTENTS

1.0 INTRODUCTION

Control of the design, engineering, procurement, and construction activities on the Project will be completed in accordance with various pre-determined standard practices and project-specific 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
- Preliminary and detailed design
- Procurement
- Construction and construction management
- Startup, testing, and checkout
- Project completion

The purpose of this appendix is to summarize the codes, standards, and practices that will be used during the engineering, procurement, and construction phases of the Project. These criteria will form the basis of the design for the structural components and systems for the Project. More specific design and construction-related specifications and criteria will be developed during preliminary and/or detailed design to support material procurement, fabrication, and construction. Section 2.0 summarizes the applicable codes and standards and Section 3.0 includes the general criteria for natural phenomena, design loads, building system, and concrete and steel design. Section 4.0 describes the structural design methodology for structures and equipment foundations. Section 5.0 describes the hazard mitigation for the Project.

2.0 DESIGN CODES, STANDARDS, LAWS, AND ORDINANCES

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 local codes and ordinances. The following laws, ordinances, codes and standards have been identified as applying to structural design and construction.

When an edition date is not indicated, the latest edition and addenda applicable at time of the start of design and construction will apply.

2.1 Federal

- Title 29, Code of Federal Regulations (CFR), Part 1910, Occupational Safety and Health Standards.

2.2 State

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

- Labor Code § 6500, *et seq*., requires a permit for construction of trenches or excavations 5 feet or deeper where personnel have to 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 Administration Code (CAC) § 2-111, *et seq*.; §s 3-100, *et seq*.; § 4-106 *et seq*.; § 5-102, *et seq*.; § 6-T8-769, *et seq*.; § 6-T8-3233, *et seq*.; § ST8-3270, *et seq*.; § 6-T8-5138, *et seq*.; § 6-T8-5465, *et seq*.; § 6-T8-5531, *et seq*.; and § 6-T8-5545, *et seq*. Adopts current edition of California Building Code (CBC) as minimal legal building standards.
- State of California Department of Transportation (Caltrans), Standard Specifications, July 1995.
- California Building Code (CBC), 2007 Edition.
- Title 8, Code of California Regulations (CCR), § 1500, *et seq*.; § 2300, *et seq*.; and § 3200, *et seq*., describes general construction safety orders, industrial safety orders, and work safety requirements and procedures.

2.3 County

- Kern County, California, Rules and Regulations.

2.4 Industry Codes and Standards

The following general design requirements and procedures will be followed in development of Project specifications regarding the use of Codes and Industry Standards.

- Specifications for materials will generally follow the standard specifications of the American Society for Testing and Materials (ASTM) and the American National Standards Institute (ANSI).
- Field and laboratory testing procedures for materials will follow standard ASTM standards.
- Design and placement of structural concrete will follow the recommended practices of the American Concrete Institute (ACI), CBC, and the Concrete Reinforcing Steel Institute (CRSI).
- Design, fabrication, and erection of structural steel will follow the recommended practices of the American Institute of Steel Construction (AISC) Code and CBC.
- Steel components for metal wall panels and roof decking will conform to the American Iron and Steel Institute (AISI) Specification for the Design of Light Gage Cold-Formed Structural Members.
- Welding procedures and qualifications for welders will follow the recommended practices and codes of the American Welding Society (AWS).
- Preparation of metal surfaces for coating systems will follow the specifications and standard practices of the Steel Structures Painting Council (SSPC), National Association for Corrosion Engineers (NACE), and the specific instructions of the coatings manufacturer.

- Design and erection of masonry materials will follow the recommended practices of the ACI Concrete Masonry Structures Design and Construction Manual and CBC.
- Plumbing will conform to the International Plumbing Code (IPC)-2006.
- Design of roof coverings will conform to the requirements of the National Fire Protection Association (NFPA) and Factory Mutual (FM).
- American Society of Civil Engineers (ASCE 7-05), Minimum Design Loads for Buildings and other Structures.
- American Institute of Steel Construction (AISC).
  - S360-05 – Specification for Structural Steel Buildings
  - S303-05 – Code of Standard Practice for Steel Buildings and Bridges
  - AISC 325-05 – Steel Construction Manual, 13th Edition
  - AISC 327-05 – AISC Earthquake Design Manual
- American Iron and Steel Institute (AISI), NAS-01 North American Specification for the Design of Cold-Formed Steel Structural Members, including 2004 Supplement.
- American Welding Society (AWS) , AWS D1.1-06, Structural Welding Code-Steel.
- American Concrete Institute (ACI).
  - ACI 318-05 − Building Code Requirements for Structural Concrete
  - ACI 530-05 − Building Code Requirements for Masonry Structures
  - ACI 350-06 − Code requirements for Environmental Engineering Concrete Structures
- American Society for Testing and Materials (ASTM).
  - ASTM A36-05 − Standard Specification for Carbon Structural Steel
  - ASTM A53-07 − Standard Specification for Pipe, Steel Black and Hot-Dipped, Zinc Coated, Welded and Seamless
  - ASTM A82-07 − Standard Specification for Steel Wire, Plain, for Concrete Reinforcement
  - ASTM A153-07 − Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
  - ASTM A185-07 − Standard Specification for Welded Steel Wire Reinforcement , Plain, for Concrete
  - ASTM A307-07 − Standard Specification for Carbon Steel Bolts and Studs. 60,000 pounds per square inch (psi) Tensile Strength
  - ASTM A325-07A − Standard Specification for Structural Bolts, Steel , Heat Treated
  - ASTM A500-07 − Standard Specification for Cold-formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
  - ASTM A563-04 − Standard Specification for Carbon and Alloy Steel Nuts

  - ASTM A572-07 − Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
  - ASTM A615/A6I5M-08 − Standard Specification Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
  - ASTM A653/A653M—04a − Standard Specification for Steel Sheet, Zinc-coated Galvanized or c-iron Alloy-coated Galvanized by Hot-dip Process
  - ASTM A992-06A − Standard Specification for Steel Structural Shapes for Use in Building Framing
- Masonry Institute of America, Reinforced Masonry Engineering Handbook.
- American Water Works Association (AWWA).
  - AWWA D100-2005 − Welded Steel Tanks for Water Storage
  - AWWA C301-99 − Prestressed Concrete Pressure Pipe, Steel Cylinder Type for Water and Other Liquids
  - AWWA C302-2004 −Standards for Reinforced Concrete Water Pipe Non-cylinder Type, Not Pre-stressed
- American Association of State Highway and Transportation Officials (AASHTO) Bridge Design Specifications, 4th Edition, 2008 Interim Revisions.
- Heating, Ventilating, and Air Conditioning Guide by American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE).
- International Plumbing Code, IPC-06.
- NFPA-01-2006, Uniform Fire Code.
- Steel Structures Painting Council Standards (SSPC).

3.0 STRUCTURAL DESIGN CRITERIA

3.1 Natural Phenomena

3.1.1 Rainfall

See Civil Design Criteria, Appendix B1

3.1.2 Wind Speed

This basic design wind speed (3-second gust) is 85 miles per hour as per CBC 2007.

3.1.3 Temperature

Systems and system component design criteria, which require ambient temperature extremes, will use 39 degrees Fahrenheit (°F) minimum winter and 97°F maximum summer dry-bulb temperatures. Design relative humidity is 20 percent in summer and 82 percent in winter.

3.1.4 Earthquake

The Project Site is located in high earthquake zone and the mapped maximum credible accelerations and design response spectrum will be determined from § 1613A of CBC 2007. The preliminary geotechnical investigation report, included under Appendix P, has denoted the Project Site as Site Class "D" with following seismic design parameters:

- Spectral Acceleration, Ss = 1.139
- Spectral Acceleration, $S_1 = 0.513$
- Site Coefficient, $F_1 = 1.045$
- Site Coefficient, $F_V = 1.5$

3.1.5 Snow

The Project Site is located in a zero ground snow load area.

3.1.6 Flood

Based on Kern County, California Flood Insurance Rate Map (FIRM) dated 29 September 1986, the Project Site is in an unmapped area and is not in the 100-year flood zone.

3.2 Design Loads, Load Combinations, and Allowable Stresses

Design loads for all structures will be determined according to the criteria described below. The plant will be designed for Occupancy Category III in accordance with CBC Table 1604.5 and the corresponding Importance Factors for wind, snow, and earthquake will be considered in the design.

3.2.1 Dead Loads (D)

Dead loads will be considered permanent loads. They consist of the weights of the structure and all equipment of a permanent or semi-permanent nature including tanks, bins, wall panels, partitions, roofing, piping, drains, electrical trays, bus ducts, and the contents of tanks and bins measured at full operating capacity. The contents of tanks and bins will not be considered for resisting overturning due to wind forces, but will be considered effective for resisting overturning for earthquake forces.

3.2.2 Live Loads (L) or Roof Live Load (L_r)

Live loads are those defined by use or occupancy of building or structure. They consist of uniformly distributed, concentrated, or moving loads. Uniform live loads are assumed unit loads which are sufficient to provide for movable and transitory loads, such as the weight of people, portable equipment and tools, planking and small equipment, or parts which may be moved over or placed on floors during maintenance operations. These uniform live loads will not be applied to floor areas which will be permanently occupied by equipment or other dead loads.

Equipment live loads are calculated loads based upon the actual weight and size of the equipment and parts to be placed on floors during dismantling and maintenance, or to be temporarily placed on or moved over floors during installation.

Consideration will be given to designing appropriate areas of the ground floor for support of heavy equipment such as construction and maintenance cranes.

Live loads may be reduced in accordance with the provisions of CBC § 1607A.9 for floors and § 1607A.11.2 for roofs. Live load reduction will not be permitted in areas where equipment laydown loads are considered.

All roof areas will be designed for live loads as indicated in CBC Subsection 1607A.11. Roof(s) will also be designed for rain ponding load effect of CBC § 1611A. All roof areas will be designed for a minimum of 20 pounds per square foot (psf) live load in addition to calculated dead loads.

3.2.3 Wind Loads (W)

Wind loads on structures, systems, and components will be determined from ASCE 7-05 and CBC 2007. Consideration will be given to along-wind and across-wind responses. A step function of pressure with height and Exposure C conditions will be used. The Importance Factor will equal 1.15. Allowance will not be made for the effect of shielding by other structures.

The overturning moment calculated from wind pressure will not exceed two-thirds of the dead load resisting moment. The uplift forces calculated from the wind load pressure will not exceed two-thirds of the resisting dead load. For determining stresses, all vertical design loads, except roof live loads, will be considered to act simultaneously with the wind pressure.

3.2.4 Traffic Loads (Tl)

Bridges, trenches, and underground installations accessible to truck loading will be designed to withstand HS20 load as defined by AASHTO Standard Specifications for Highway Bridges. Maintenance or construction crane or bridge crane loads will also be considered where applicable.

3.2.5 Earthquake Loads (E)

Loads will be determined in accordance with the requirements specified in CBC 2007 § 1613A and spectral accelerations and site class listed in Section 3.1.4.

3.2.6 Construction/Erection Loads (C)

Construction / erection loads are temporary forces caused by erection of structures or equipment. The integrity of the structures will be maintained with or without use of temporary framing struts or ties and cable bracing.

3.2.7 Vibration Loads (V)

Vibration loads are defined as those forces that are caused by vibrating machinery such as pumps, blowers, fans, generators and compressors. Supports and foundations for vibrating equipment will be designed to limit vibrations to levels that are acceptable for equipment operation and human tolerance.

3.2.8 Other Loads (R)

Other loads such as impact, blast, temperature, hydrostatic and earth pressures will be considered when applicable.

3.2.9 Load Combinations

At a minimum, buildings and other structures will be designed to resist the loads combinations specified in CBC 2007 § 1605A for strength or allowable stress design.

3.3 Buildings

General design criteria for the architectural systems are discussed in the following subsections.

3.3.1 Architectural System

General design criteria for materials and installation of architectural systems or components will be as follows:

- **Exterior Walls.** These will be metal wall panel systems of the factory assembled or field erected type with exposed fasteners and minimum thickness of exterior sheet of 24 gauge galvanized steel. Installed walls will be watertight and will provide a "U" factor in accordance with the California Administrative Code, Title 24 and the ASHRAE Handbook. Added insulation will be provided for sound absorption on walls enclosing equipment generating excessive noise.
- **Interior Walls.** Where durability is required, interior walls may be constructed of concrete block masonry, structurally-designed and reinforced as required. In offices, shops, etc., metal studs with gypsum board will usually be used to form interior partitions. Insulation for sound control will be used where required by design.
- **Fire Exits and Doors.** Fire exits will be provided at outside walls as required by code. Exit signs will be provided. Fire doors will bear an Underwriters Laboratory (UL) certification level for class of opening and rating for door, frame, and hardware. Doors will conform to hollow metal door requirements and have fillers adequate to meet the fire rating.
- **Large Access Exterior Doors.** Large access exterior doors will be rolling steel type with weather seals and windlocks. Components will be formed from galvanized steel, factory assembled, and field painted. Doors will be motor or manually operated.
- **Metal Roof Deck and Insulation System.** Roof deck and insulation system will be fluted steel decking with minimum depth of 1-1/2 inches. The deck will have interlocking side laps. The completed roof system will carry a UL Class 90 rating in accordance with UL 580. The roof system will have a minimum slope of 1/4 inch per foot. Deflection of the roof panels will not exceed 1/180 of their span.

- **Painting.** Exterior steel material that is not galvanized or factory finished will be painted. Painted color will match or harmonize with the color of the exterior face of the wall panels.
- **Color Schemes.** Color schemes will be selected for overall compatibility and based on owner preferences.

3.3.2 Prefabricated Metal Buildings

Prefabricated metal buildings (packaged to include exterior doors, wall louvers, windows, skylights, and related enclosure components) will be furnished as follows:

- **Building Enclosure.** Building enclosures will be of manufacturer's standard modular rigid frame construction with tapered or uniform depth rafters rigidly connected at ends to pinned-base tapered or uniform depth columns. Purlins and girts will be cold-formed "C" or "Z" sections conforming to Specifications for Design of Cold-Formed Steel Structural Members of American Iron and Steel Institute. All other members will be hot-rolled shapes conforming to Specification for Design, Fabrication and Erection of Structural Steel for Buildings of AISC. Metal roof coverings will be of pre-finished standing seam panels of 24 gauge minimum.
- **Steel.** Cold-formed components will conform to ASTM A570, Grade E, 42,000 psi minimum yield for material thickness equal to or less than 0.23 inch, or to ASTM A375, 50,000 psi minimum yield for high tensile strength purlin or girt sections with material thickness equal to or less than 0.23 inch. Roof covering and wall covering will conform to ASTM A446, Grade A, galvanized 33,000 psi minimum yield. All cold-formed components will be manufactured by precision roll or break forming.

3.4 Concrete Structures

Reinforced concrete structures will be designed in accordance with ACI 318-05, Building Code Requirements for Reinforced Concrete and the CBC.

3.4.1 Materials

The materials described below will be specified and used as a basis for design.

- **Reinforcing Steel.** Reinforcing steel will meet the requirements of ASTM A615, Grade 60.
- **Cement.** Cement used in all concrete mixes will be Portland cement meeting the requirements of ASTM C150 and will be resistant to sulfates in the soil. Type V cement or alternately a combination of cement Type II, Class F Flash, and Ground Granulated Blast Furnace Slag (GGBFS) can be used.
- **Aggregates.** Fine aggregates will be clean natural sand. Coarse aggregates will be crushed gravel or stone. All aggregates will meet the requirements of ASTM C33.
- **Admixtures.** Plasticizers and retarders may be used to control setting time and to obtain optimum workability. Air entrainment will be per ACI requirements. Calcium chloride will not be permitted. Interior slabs to be trowel finished.
- **Water.** Clean water of potable quality will be used in all concrete.

3.4.2 Design

The structural concrete and steel reinforcing strength combinations will be used as follows:

- Concrete strength 4,000 psi minimum (at 28 days)
- Reinforcing steel – ASTM A615, Grade 60 or ASTM A706

3.4.3 Mixes

Concrete strength test method will conform to ASTM C39.

3.4.4 Reinforcing Steel Test

Mill test reports will be obtained from the reinforcing steel supplier and retained in Project records.

3.5 Structural Steel

Steel framed structures will be designed in accordance with the CBC and the AISC Specification for the Structural Steel Building. In addition, steel framed structures will be designed in accordance with the criteria discussed in the following subsections.

3.5.1 Materials

Structural steel shapes, plates, and appurtenances for general use will conform to ASTM A36 and A992. Structural steel required for heavy framing members may consider use of ASTM A572. Structural steel required for tube sections will conform to ASTM A500, Grade B. Connection bolts will conform to ASTM A325. Connections will conform to AISC Manual of Steel Construction. Welding electrodes will be as specified by the AWS. All structural steel will be shop primed and finish painted after fabrication or galvanized.

3.5.2 Design

Steel structures, braced or rigid frame, will be designed in accordance with Steel Construction Manual and ANSI/AISC-360-05, Specification for Structural Steel Buildings.

Suspended concrete slabs will be considered as horizontal diaphragms after setup and curing. Deflections of the support steel will be controlled to prohibit “ponding” of the fresh concrete as it is placed. Metal roof decks attached with welding washers or fasteners may be considered to provide a structure with lateral force diaphragm action.

Connections will be in accordance with AISC standard connection design for field bolted connections.

3.6 Earthquake Design Criteria

This section provides the general criteria and procedures which will be used for Earthquake design of building and non-building structures.

The Project is located in high Earthquake Zone and mapped maximum considered accelerations for 0.2 second and 1 second will be determined from CBC 2007 Figure 1613.5(3) and 1613.5(4), respectively. The Earthquake performance objectives for this facility are as follows:

- Resist minor levels of ground motion without damage
- Resist moderate levels of ground motion without structural damage, but possibly experience some non-structural damage
- Resist major levels of ground motion without collapse, but possibly with some structural as well as non-structural damage

To achieve these objectives, the Project will be designed in accordance with the CBC 2007 and ASCE 7-05.

Structures having one or more of the features listed in ASCE 7-05 Table 12.3-1 and Table 12.3.2, will be designated as having a horizontal (plan) and vertical structural irregularity, respectively. All structures, regular or irregular, will be designed by static or dynamic procedures in accordance with ASCE 7-05 Chapter 12 for Building Structures, Chapter 13 for Non-Structural Components and Chapter 15 for Non-Building Structures.

Provisions for torsional irregularity, overturning, discontinuous lateral load-resisting element, story drift limitation, and P-Delta effects, etc., will be considered in accordance with Chapter 12 of ASCE 7-05.

3.6.1 Buildings

The building structural system will be constructed of steel framing supported on footings tied together by perimeter grade beams and floor slab. Lateral forces will be resisted by moment-frames in the short direction, braced-frames in the long direction, and by horizontal bracing in the roof steel.

Earthquake forces will be computed by Chapter 12 of ASCE 7-05. The Earthquake dead load (D), will include the total dead load of the structural system, architectural enclosure, and the weight of any attached permanent equipment.

3.6.2 Non-Building Structures

Non-building structures such as tanks and equipment skids will be designed to resist Earthquake forces in accordance with ASCE 7-05 Chapter 15.

3.6.3 Non-Structural Components

Non-structural components and equipment, including piping and cable tray and their supports, will be designed in accordance with ASCE 7-05 Chapter 13.

4.0 STRUCTURAL METHODOLOGY

Appropriate analysis and design tools (software) and engineering methods will be utilized for the design of steel and concrete structures and their foundations required for supporting equipment, pipes, and buildings. Applicable loads and load combinations will used. The analysis and design of the structural systems and their foundations will be in accordance with the referenced state, county, and industry codes and standards in Section 2.0. Static and dynamic analysis, when applicable, will be performed. Foundation design will conform to the recommendations of the Project Site developed Geotechnical Investigation Report.

Equipment, pipe, and building structures and equipment will be securely anchored to the foundation using cast-in-place steel anchor bolts designed to resist imposed loads.

All structural analysis and design calculations will be documented and major items will be checked and sealed by California state registered structural engineer. All structural steel, concrete, piling, and foundation drawings will sealed by California state registered structural engineer.

5.0 NATURAL PHENOMENA HAZARDS MITIGATION

Structural, system, and components will be designed to mitigate natural phenomena hazards such as wind, rain, and earthquake. This section addresses the structural design criteria used to mitigate such hazards.

5.1 Earthquake Hazard Mitigation Criteria

Based on the preliminary geotechnical report (Appendix P), the Project Site is not in any active or potentially active fault zones. The closest known active faults are the San Andreas Fault approximately 19 miles to the west, the White Wolf Fault approximately 22 miles to the southeast, and the Pleito Thrust located approximately 25 miles south of the Project Site. Based on the available geological data and in the absence of any active faults passing through the Project Site, the potential for primary ground rupture, liquefaction, subsidence ground failure, landslides, volcanic activity, tsunamis, seiches, and differential soil settlement is either low or non-existent.

The Earthquake design criteria for the Project will be based on the following considerations:

- Compliance with applicable laws, ordinances, regulations, and standards (LORS)
- Life safety
- Structural behavior and performance
- Reliability of the power plant
- Financial impacts from Earthquake-induced outages
- Earthquake probability and magnitude

The Project Earthquake design criteria will be developed to incorporate these considerations using a systematic approach to correlate performance criteria with assumed risk level. The following procedure will be used to establish the design criteria:

- The Earthquake risk associated with each source will be assessed considering historical magnitudes.
- Acceleration levels for various structural frequencies will be based on ASCE 7-05 Figure No. 11.4-1, Design Response Spectrum.

- Appropriate design criteria and analysis methods will be established for each major power plant structure, equipment, and component consistent with the Earthquake performance criteria.

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

- Appropriate analysis techniques will be employed to calculate structure specific Earthquake loads.
- Plant structures, equipment, piping, and other components will be designed to resist the Project-specific Earthquake loads.
- All equipment will be positively anchored to its supporting structure. Nominal uplift capacity will be provided in the absence of calculated overturning forces.
- Anchorages will be designed to resist the Project-specific Earthquake loadings.
- The design of piping connections to structures, tanks, and equipment will consider the differential Earthquake displacements between components.
- Adjacent structures will be 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.

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

- Resist minor earthquake without damage. Plant remains operational.
- Resist moderate earthquake without structural damage but with some non-structural damage. Plant remains operational or is returned to service following visual inspection and minor repairs.
- Resist major earthquake without collapse but with some structural and non-structural damage. Plant is returned to service following visual inspection and minor repairs.

5.2 Meteorological and Climatic Hazards Mitigation

Meteorological and climatic data will form the design basis for the Project. Portions of the data and the design bases that pertain to structural engineering have been provided in this appendix.

Specific design features that will be incorporated 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.
- Plant drainage systems will be designed to convey the runoff from a rainfall event in accordance with Civil Engineering Design Criteria listed in Appendix B1.
- Ground floor levels of structures will be placed above probable flood levels.
- The Project Site will be graded to convey runoff away from structures and equipment.

The foregoing design features will be incorporated in accordance with 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 provided by these features.

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Appendix B-3

Mechanical Engineering

APPENDIX B3
MECHANICAL ENGINEERING DESIGN CRITERIA
TABLE OF CONTENTS

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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/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. The general mechanical design criteria defined herein form the basis of the design for the mechanical components and systems of the Project. More specific design information is 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.

Section 2.0 summarizes the applicable codes and standards and Section 3.0 includes the general design criteria for piping, valves, insulation, lagging, and freeze protection.

2.0 APPLICABLE LAWS, ORDINANCES, REGULATIONS, AND STANDARDS

The design and construction of the Project will conform to the following laws, ordinances, regulations, and standards (LORS). When an edition date is not indicated, the latest edition and addenda applicable at start of detailed design will apply.

2.1 Federal

- OSHA – Occupational Safety and Health Administration, Department of Labor
- 29 Code of Federal Regulations (CFR) 1910 – Occupational Safety and Health Standards
- 29 CFR 1926 – Safety and Health Regulations for Construction

2.2 State

- California Administrative Code, Title 8
  - Chapters 4 through 7, Groups 20 Flammable Liquids, Gases, and Vapors
  - Group 27, Fire Protection

- CBC – California Building Code

2.3 County

- Kern County, California, Rules and Regulations.

2.4 Industry Codes and Standards

- ABMA – American Boiler Manufacturer’s Association
- AFBMA – Antifriction Bearing Manufacturers Association
- AGMA – American Gear Manufacturers Association
- AMCA – Air Movers Control Association
- ANSI – American National Standards Institute
- API – American Petroleum Institute
- ASCE – American Society of Civil Engineers
- ASHRAE – American Society of Heating, Refrigeration and Air Conditioning
- ASME – American Society of Mechanical Engineers
  - Section I – Power Boilers
  - Section II – Materials Specification
  - Section V – Non-destructive Examination
  - Section VIII – Unfired Pressure Vessels
  - Section IX – Welding and Brazing Qualifications
- ASNT – American Society for Non-destructive Testing
- ASTM – American Society for Testing and Materials
- AWS – American Welding Society
- AWWA – American Water Works Association
- CEMA – Conveying Equipment Manufacturers Association
- EJMA – Expansion Joint Manufacturing Association
- HEI – Heat Exchange Institute
- HI – Hydraulic Institute Standards
- IEEE – Institute of Electrical and Electronics Engineers
- ISA – Instrument Society of America
- MSS – Manufacturers Standardization Society of the Valve and Fittings Industry
- National Fire Protection Association (NFPA) codes
- NBS – National Bureau of Standards

- NEC – National Electrical Code
- NEMA – National Electrical Manufacturers Association
- PFI – Pipe Fabrication Institute
- SSPC – Steel Structures Painting Council, Volume 2
- TEMA – Tubular Exchanger Manufacturers Association
- UFC – Uniform Fire Code
- UL – Underwriters Laboratories
- USEPA – U.S. Environmental Protection Agency

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.

3.0 MECHANICAL ENGINEERING GENERAL DESIGN CRITERIA

3.1 Piping

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

3.1.1 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 will be the maximum of:

- The set or burst pressure of a relief device mounted in the line.
- The set or burst pressure of a relief device installed on equipment that is connected to the line, adjusted accordingly to account for static head and friction loss.
- If the system has no relief device or can be isolated from a relief device, the maximum pressure upstream equipment can generate (e.g., pump shutoff pressure).
- The maximum sustained pressure that may act on the system plus the applicable design margin.

The process piping design pressures will be in accordance with applicable codes. All design pressure values will be rounded up to the next 5 pounds per square inch (psi) increment unless otherwise specified.

The design temperature of a piping system will be based on:

- The maximum sustained temperature which may act on the system plus the applicable design margin unless otherwise specified.

- If a heat exchanger of a piece of equipment in which heat is being removed can be taken out of service or bypassed, then the line downstream of that equipment should be designed for the resulting higher temperature.

3.1.2 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 for Power Block, B31.3-Process Piping, and other codes and standards referenced in Section 2, Codes and Standards. Pipeline will be in accordance to related Practice/Standards of CFR/U.S. Department of Transportation (DOT). Pipe stress analysis will be performed in accordance with ASME. All pipe supports will be suitable to restrain the piping where subjected to external loads as stipulated by the Uniform Building Code (UBC) – Seismic and Wind Load Criteria.

Material selection will generally be based on the design temperature, composition of the process fluid, and service conditions.

3.1.3 Piping Materials

- Piping materials will be in accordance with applicable ASTM and ASME standards. Materials to be incorporated in permanent systems will be new, unused, and undamaged.

3.1.4 Cathodic Protection

Where required, underground pressure piping steel will be cathodically protected from aboveground piping and other steel components. Isolation will be achieved by installation of isolation flanges with insulating gaskets, tubes, and washers.

3.1.5 Piping Fabrication

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

3.1.5.1 Welder Qualification and Welding Procedures

Welding procedures, welders, and welding operators will be qualified in accordance with ASME Section IX code requirements.

Backing rings will not be allowed for shop or field welds except where specifically permitted.

3.1.5.2 Non-destructive Examination and Inspection

Inspection and testing of piping will be performed in accordance with the requirements of ASME B31.1 or B31.3. Non-destructive examination 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 QCI, Standard for Qualification and Certification of Welding Inspectors.

- Non-destructive examination will be performed by personnel certified in accordance with ASNT Recommended Practice SNT-TC-IA.
- Radiographic examination will be performed on welds or welds to pressure retaining components as required by ASME B31.1 or B31.3 CODE.
- Magnetic particle, ultrasonic and liquid penetrant examination will be performed as required by ASME B31.1 or B31.3 Code.

3.1.6 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 for pipe supports.

3.1.6.1 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 or B31.3. Seismic design of piping systems will be in accordance with criteria as stipulated by the CBC.

3.2 Insulation and Lagging

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

3.2.1 Insulation Materials and Installation

Insulation materials will be mineral fiber or calcium silicates, with aluminum jacketing. Fiberglass insulation may be used. Insulation materials will not contain asbestos.

Personnel protection insulation on piping and equipment will be designed to limit outside lagging surface temperature to a maximum as indicated by OSHA at 70°F ambient and wind speed of 10 miles per hour.

3.2.2 Lagging Materials and Installation

All insulated surfaces of equipment, ductwork, piping, and valves will be lagged, except where removable covers are used.

3.3 Rotating Equipment

Rotating equipment specifications will be developed for each specific type of equipment. Each specification will reference applicable industry standards and codes.

General service pumps will comply with ANSI B73.1 or API 610. Pump and driver will be mounted on a common foundation. Vertical pumps will comply with Hydraulic Institute Standards (HI).

Firewater pump, driver and accessories will comply with NFPA 20.

The steam turbine generator (STG) and the combustion turbine generator (CTG) will be based on API 612 and the CTG will be based on API 616, latest editions.

3.4 Pressure Vessels

Vessels will be designed and built in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or Division 2 for high pressure vessels, latest edition and addenda. In addition, the vessels and supports will be designed for seismic loading in accordance with the CBC 2007 and wind loading in accordance with ASCE 7-02. Finite Element Analysis (FES) and dynamic analysis will be applied as appropriate to reactors, high temperature and tall vessels.

3.5 Storage Tanks

Field-fabricated tanks will be designed, erected, and tested in accordance with AWWA D 100 or API 650. The make-up water storage tank which also provides firewater storage will also conform to NFPA requirements. A Sacrificial Aluminum Sheet Anode (SALSA) cathodic protection system will be provided at the bottom of the tank. Tanks containing demineralized water will be carbon steel with a phenolic epoxy liner.

3.6 Heat Recovery Steam Generators

The heat recovery steam generators (HRSG) will be designed and constructed in accordance with ASME Boiler and Pressure Vessel Code, Section I, latest edition and addenda. The feedwater heater section will be designed and constructed per ASME Section I or VIII. All sections will utilize finned-tube design with materials suitable for operating conditions. All steam drums will be remote mounted. The seismic design criteria will be in accordance with CBC 2007 and wind loading in accordance with ASCE 7-02.

3.7 Shell and Tube Heat Exchangers

Shell and tube heat exchangers will be designed and built in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest edition and addenda.

3.8 Air Cooled Heat Exchangers

Air cooled heat exchangers will be designed and built in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest edition and addenda. In addition, the support (structural members of the air coolers) will be designed for seismic loading in accordance with CBC 2007 and wind loading in accordance with ASCE 7-05.

4.0 COOLING TOWERS

Cooling towers will be designed in accordance with Cooling Tower Institute (CTI) Standards. The cooling towers will be field erected. This could be a wood or fiberglass tower. In addition, the tower will be designed for seismic loading in accordance with CBC 2007 and wind loading in accordance with ASCE 7-05.

Appendix B-4

Electrical Engineering

APPENDIX B4
ELECTRICAL ENGINEERING DESIGN CRITERIA
TABLE OF CONTENTS

TABLE OF CONTENTS

1.0 INTRODUCTION

The purpose of this appendix is to summarize the Codes and Standards and design criteria and practices that will be used during the Project. The general design criteria defined herein form the basis of the design for the major components and systems of the Project. More specific design information will be developed during detailed design to support equipment and installation specifications.

2.0 GENERAL

The power plant electrical distribution system configuration is indicated on the following Overall One Line Diagrams: A3RW00-0-SL-6-00-1, 2, 3 & 4.

The power plant will have a 230 kV (kilovolt) transmission line interconnection to the Pacific Gas & Electric (PG&E) Midway Substation. The details of the 230 kV transmission lines to the PG&E Midway Substation are described in the Application for Certification (AFC) Section 4.0 - Electrical Transmission.

Startup power for the combustion turbine generator (CTG) will be obtained by back feeding from the 230 kV grid through the main and unit auxiliary transformers.

Standby diesel generators will provide essential service power in the event of a grid failure.

This document includes typical relay and meter types. For additional relay or meter information refer to the manufacturers' web sites for the indicated devices.

3.0 CODES AND STANDARDS

Electrical equipment and materials will conform to the applicable provisions of the following Codes and Standards:

- American National Standards Institute (ANSI)
- Institute of Electrical and Electronics Engineers (IEEE)
- National Electrical Manufacturers Association (NEMA)
- American Society for Testing and Materials (ASTM)
- Underwriters Laboratories (UL)
- Factory Mutual (FM)
- Occupational Safety and Health Act (OSHA)
- National Fire Protection Association (NFPA)
- American Petroleum Institute (API)
- National Electrical Safety Code (NESC) (Only for 230 kV work)
- National Electrical Code (NEC)
- Insulated Cable Engineers Association (ICEA)

- Association of Edison Illuminating Companies (AEIC) (Only for medium voltage (MV) cable)
- Illuminating Engineering Society of North America (IESNA)
- International Electrotechnical Commission (IEC) Note IEC standards may be used on motors and other electrical equipment such as large sync motor starting LCIs (Load commutated inverter) manufactured outside the U.S.

4.0 SYSTEM GROUNDING

System grounding will be as follows:

- 230 kV System: Combustion turbine generators (CTG) and steam turbine generator (STG) generator step up transformer (GSU) solidly grounded at high voltage (HV) wye winding
- 18 kV System: CTG and STG high resistance grounded at the generator neutrals
- 13.8 kV System: Low resistance grounded to 400 ampere (A), 10 seconds
- 4.16 kV System: Low resistance grounded to 400 A, 10 seconds
- 0.48 kV System: High resistance grounded with pulse detection grounding system
- 208/120 volt (V) System: Solidly grounded at distribution transformer wye winding
- 125 volt direct current (Vdc) System: Ungrounded with ground detection at battery chargers

5.0 ENVIRONMENTAL

Medium Voltage (MV) and Low Voltage (LV) switchgear, MV and LV MCCs, batteries, chargers, uninterruptible power systems (UPS), and distributed control systems input output (DCS I/O) racks will be located indoors in pre-fabricated electrical power distribution centers (PDC) with redundant heating, ventilation, and air conditioning (HVAC) units.

Electrical equipment for outdoor environments will be housed in NEMA 3R or NEMA 4 weatherproof enclosures.

Conduit entry to outdoor enclosures will not be from the top unless an appropriate waterproof connection is used.

Enclosures for all equipment will be in accordance with NEMA standards and type number and will be suitable for their location as follows:

- NEMA 1 Indoors (General Purpose)
- NEMA 3R Outdoors and Indoors (in wet locations)
- NEMA 4 Outdoors and Indoors (in wet locations – dust tight)
- NEMA 4X Outdoors - Indoors in wet and corrosion resistant locations
- NEMA 7 Classified Areas, Class I, Division 1, Groups B, C, and D
- NEMA 9 Classified Areas, Class II, Division 1
- NEMA 12 Non-environmentally-controlled indoor dusty areas

6.0 PLANT VOLTAGE TABLE

Service	Motor or Generator Rated Voltage	System Voltage
PG&E Utility Interconnection	-	230 kV
CTG and STG Generator Voltage	18 kV	18 kV
ASU and CO_2 Sync Motors with LCI Soft Starting and Turbo-expander Gen Set	13,800 V	13,800 V
ASU and AGR Sync and Ind Motors with Direct on Line Starting	13,200 V	13,800 V
Medium Voltage motors 300 HP to 3,500 HP	4,000 V	4,160 V
Low Voltage motors from 0.75 HP to 250 HP and motor operated valves (3-Phase)	460 V	480 V
Standby Generator Voltage	4160 V	4160 V
Street or area flood lighting	-	480 V
Lighting, receptacles, space heaters, heat tracing	-	208/120 V
Motors 0.75 HP and below (1-Phase)	115 V	120 V
UPS power (1-Phase)	-	120 V
Protection system, LV & MV switchgear controls, UPS input power	-	125 Vdc
Emergency lube oil pump motors and other dc motors less than 30 HP	-	125 Vdc
DCS instrumentation and controls	-	24 Vdc

7.0 POWER DISTRIBUTION CENTERS

PDCs will be pre fabricated buildings arranged with three separate rooms as follows: One for MV and LV electrical distribution equipment, one for the flooded cell batteries, and one for the DCS racks.

The power plant PDCs will be factory assembled, wired, tested and operational in metal enclosures containing various combinations of electrical power and control equipment. The PDCs will be sized for the equipment and vendor recommended operating and maintenance access. The PDCs will be furnished with heating and air conditioning, fire detection and fire alarm systems, power distribution, lighting, and grounding.

The PDCs will be elevated above grade with sufficient space for cable trays and conduits to enter from below.

The medium voltage arc resistant switchgear will have a plenum to allow for free expansion and travel of gas and material to the outdoors. In PDCs with only low voltage switchgear, the ceiling height will be at least 11 feet so that a plenum will not be required.

8.0 AREA CLASSIFICATION

Area classification will be as defined by NEC supplemented by the recommendations in the NFPA standard and API.

Process areas will be classified where required as Class I, Division 2, Group D (and Group B when the fuel contains more than 30 percent hydrogen by volume).

Generator hydrogen control cabinets, valves, and storage bottles will be classified as Class I, Division 2.

Areas where combustible dust may be present will be classified as Class II.

9.0 230 KV SWITCHYARD

The 230 kV switchyard will have the following features:

- Configured as a breaker and a half scheme
- Rated for 245 kV maximum operating voltage and 900 kV Basic Impulse Level (BIL)
- Two 230 kV transmission lines to PG&E Midway Substation with each line sized for the total power plant output
- Metal Oxide 192 kV lightning arrestors with a 158 kV Maximum Continuous Operating Voltage (MCOV) rating on the transmission line exits to PG&E Midway substation
- Main busbars sized for 3,000 A using aluminum bus
- Breakers will have a 3,000 A, 63 kA symmetrical interrupting rating
- Breakers will be dead tank type SF6 insulated with dual trip coils
- Breakers will have C800 relay class current transformers
- Revenue metering class current transformers on each line exit to PG&E
- Three potential transformers on each line and transformer exit
- Manual group operated vertical break disconnect switches rated 3,000 A
- Lightning protection via overhead shield wires and masts
- Composite insulators on the transmission lines with extended creepage distances
- Porcelain-post insulators with extended creepage distances
- Relay building with HVAC
- Dual 125 Vdc battery systems

The transmission line and bus protective relays will be microprocessor based with fiber optic communications to PG&E Midway Substation via dual optical ground wires (OPGW). Two separate transmission line relays with current differential functions with phase and ground back up functions (GE UR L90 and SEL 311L) will be used along with an additional third relay (GE UR D60) with step distance functions to be used in a communications-aided scheme.

The 230 kV transformers will have redundant differential relays with phase and ground overcurrent back up functions (GE UR T60 and SEL 387A). Breaker failure relays with sync check (GE UR C60) will be used on each 230 kV breaker.

Each main bus will have a bus differential relay (GE UR B90). Each breaker will have a breaker failure relay (GE UR C60).

A digital fault and disturbance recording system (GE DDFR) will use communications to retrieve Fault, Disturbance, and Sequence of Event records that are captured by the protection relays distributed throughout a substation.

Communications processors (SEL-2032) will be used to interface to the DCS via fiber optic cables.

The 230 kV transmission line exit revenue metering will be fed from revenue metering class current transformers (CTs) and potential transformers (PTs) located on the transmission line exits to PG&E Midway Substation. California Independent System Operator (CAISO) metering will be via CAISO-approved multifunction meters (ION 8600A), which will be connected to a Remote Intelligent Gateway (RIG) to communicate with CAISO.

The 230 kV transformer meters (ION 8600A) for CAISO metering use will be fed from three revenue metering class CTs located in the transformer bushings and three PTs located on the 230 kV transformer exits.

10.0 TRANSFORMERS

The main features of the plant transformers are described below. Refer to the One Line Diagrams for the transformer MVA ratings.

10.1 CTG and STG Step Up Transformers

The CTG and STG step up transformers will have the following features:

- 18 kV Delta to 238 kV grounded wye, 3 phase, 60 Hz, core form, copper windings
- ONAN/ONAF/ONAF, 65 Deg C, Impedance (Z) = 9 % (ONAN MVA base) (ONAN = Mineral oil natural convection flow through cooling equipment and in windings, ONAF = Mineral oil cooled by forced air cooling equipment)
- HV Deenergized tap Changer (DETC), full capacity taps, plus minus 2 x 2 1/2 %
- HV BIL = 750 kV, LV and HV Neutral (HO) BIL = 150 kV
- Metal Oxide 192 kV lightning arrestors with a 158 kV Maximum Continuous Operating Voltage (MCOV) rating
- HV condenser-type porcelain bushings rated 900 kV BIL with extended creepage distances
- LV cover mounted bushings for iso phase bus (IPB) flanges
- Conservator oil preservation system with bladder and silicon gel breather
- Qualitrol® oil, temp, gas accumulation alarm relays and gauges
- Sudden pressure relay and pressure relief device
- Transformer temperature monitoring system (GE MO150)
- Transformer fault gas and water in oil monitor (GE Hydran)
- ANSI standard factory tests including heat run and noise test with certified test reports

10.2 ASU Step Down Transformer

The ASU 230-13.8 kV step down transformer will have the following features:

- 230 kV Delta to 13.8 kV Low Resistance grounded wye, 3 phase, 60 Hz, copper windings
- ONAN/ONAF/ONAF, 65 Deg C, Z= 9 % (ONAN MVA base)
- HV DETC, full capacity taps, plus minus 2 x 2 1/2 %
- HV BIL = 750 kV, LV and HO BIL = 110 kV
- Metal Oxide 192 kV lightning arrestors with a 158 kV Maximum Continuous Operating Voltage (MCOV) rating
- HV condenser type porcelain bushings rated 900 kV BIL with extended creepage distances
- LV cover mounted bushings for IPB flanges
- Conservator oil preservation system with bladder and silicon gel breather
- Qualitrol oil, temp, gas accumulation alarm relays and gauges
- Sudden pressure relay and pressure relief device
- Transformer temperature monitoring system (GE MO150)
- Transformer fault gas and water in oil monitor (GE Hydran)
- ANSI standard factory tests including heat run and noise test with certified test reports

10.3 Unit Auxiliary Step Down Transformers

The 18-13.8 kV unit auxiliary step down transformers will have the following features:

- 18 kV delta to 13.8 kV low resistance grounded wye, 3 phase, 60 Hz, copper windings
- ONAN/ONAF/ONAF, 65 Deg C, Z= 9 % (ONAN MVA base)
- Reinhausen load tap changer, full capacity taps, plus minus 10 percent, 16 step
- Beckwith M-2001C LTC controller to control LV voltage
- HV BIL = 150 kV
- LV and XO BIL = 110 kV
- HV cover mounted bushings for IPB flanges
- LV cover mounted bushings for non segregated bus duct flange
- Conservator oil preservation system with bladder and silicon gel breather
- Qualitrol oil and temp alarm relays and gauges
- Qualitrol sudden pressure relay
- ANSI stnd factory tests including heat run and noise test on one unit with certified test reports

10.4 13.8-4.16 kV Unit Auxiliary Step Down Transformers

The 13.8-4.16 kV unit auxiliary step down transformers will have the following features:

- 13.8 kV delta to 4.16 kV low resistance grounded wye, 3 phase, 60 Hz, copper windings
- ONAN/ONAF/ONAF, 65 Deg C, Z= 7 % (ONAN MVA base)
- HV DETC, full capacity taps, +/- 2 x 2.5 percent
- HV BIL = 110 kV
- LV and XO BIL = 60 kV
- HV side mounted bushings in a full height HV cable termination compartment
- LV side mounted bushings for non segregated bus duct flange
- Sealed tank oil preservation system
- Qualitrol oil and temp alarm relays and gauges
- Qualitrol sudden pressure relay
- ANSI standard factory tests including heat run and noise test on one unit with certified test reports

10.5 13.8-0.48 kV Auxiliary Step Down Transformers

- 13.8 kV delta to 0.48 kV high resistance grounded wye, 3 phase, 60 Hz, copper windings
- ONAN/ONAF, 65 Deg C, Z= 7 % (ONAN MVA base)
- HV DETC, full capacity taps, plus minus 2 x 2.5 percent
- HV BIL = 110 kV
- LV and XO BIL = 30 kV
- HV side mounted bushings in a full height HV cable termination compartment
- LV side mounted bushings for non segregated bus duct flange
- Sealed tank oil preservation system
- Qualitrol oil and temp alarm relays and gauges
- Qualitrol sudden pressure relay
- ANSI standard factory tests including heat run test on one unit with certified test reports

10.6 4.16-0.48 kV Aux Step Down Transformers

- 4.16 kV delta to 0.48 kV high resistance grounded wye, 3 phase, 60 Hz, copper windings
- ONAN/ONAF, 65 Deg C, Z= 7 % (ONAN MVA base)
- HV DETC, full capacity taps, plus minus 2 x 2.5 percent

- HV BIL = 60 kV
- LV and XO BIL = 30 kV
- HV side mounted bushings in a full height HV cable termination compartment
- LV side mounted bushings for non segregated bus duct flange
- Sealed tank oil preservation system
- Qualitrol oil and temp alarm relays and gauges
- Qualitrol sudden pressure relay
- ANSI standard factory tests including heat run test on one unit with certified test reports

11.0 CTG AND STG GENERATOR CIRCUIT BREAKERS

CTG and STG generator circuit breakers (GCB) will be installed outdoors on a galvanized steel platform in line with the iso-phase bus. The GCB will be rated at 105 percent of the maximum continuous current. The GCB will be supplied with dual trip coils, bus side motor operated disconnect switch, and potential and current transformers. The GCB will have the interrupting ratings shown on the One Line Diagrams.

12.0 CTG AND STG RELAYING

Dual generator protection micro-processor based relays (GE G60 and Beckwith M-03425A) with communications to the turbine control system (TCS) will be used. On each CTG and STG that has a generator breaker, an additional generator breaker failure relay (GE C60) will be used.

13.0 CTG AND STG METERING

Generator metering will use a micro-processor based multi-function meter (Nexus 1250) with communications to the turbine control system and to the DCS.

14.0 ISO PHASE BUS

The iso-phase bus will be aluminum conductor braced for the maximum available fault current for each section of bus.

The iso-phase bus will be rated at least 105 percent of the nominal generator output with total temperature limits of 80 degrees Celsius (°C) on the enclosure and 105°C on the conductor.

Filtered drains will be to drain off moisture due to condensation.

The iso-phase bus PTs, surge capacitors and lightning arresters located between the generator breaker and the main transformer will be integrated in the generator breaker.

15.0 MV SWITCHGEAR

The 13.8 kV and 4.16 kV switchgear will be indoor, metal clad switchgear, arc resistant Type 2 per IEEE C37.20.7. Power bus will be copper and will be insulated with flame retardant, non-hygroscopic insulation.

The 13.8 kV and 4.16 kV switchgear will use vacuum draw out circuit breakers with a remote racking device. Two high breaker construction will be used. All breakers will be remotely controlled from the DCS.

The 18-13.8 kV unit auxiliary transformers will have a differential relay with phase and ground overcurrent back up functions (SEL 387A).

The 13.8 kV main incoming breakers will have breaker failure protection included in the unit auxiliary transformer differential relay.

The 13.8 kV switchgear will have high impedance bus differential relays (SEL 587Z).

The 13.8-4.16 kV auxiliary transformers will be primary-protected by a feeder protection relay (SEL 551). The 13.8-4.16 kV transformers will have a differential protection relay (SEL 587).

The 4.16-0.48 kV transformers will be protected by a feeder protection phase and ground over current relay (SEL 551).

Each 13.8 kV and 4.16 kV breaker will be electrically operated and remotely controlled from the DCS.

MV switchgear protective relays will trip via lock out relays which will have coils monitored by the protective relays.

Motors rated 3,000 HP and larger will be fed from circuit breakers and will have microprocessor-based motor relay (SEL 710) with a communications port connected to the DCS. Motor differential protection using self balancing current transformers will be used on circuit breaker fed motors. Motor stator resistant temperature detectors (RTDs) will be wired to the motor relay.

Each 13.8 kV and 4.16 kV breaker will have a power measurement ION 6200-EP1 display meter with a communications port connected to the DCS.

A manual bus transfer scheme with make before break circuitry with momentary paralleling of the unit two auxiliary transformers will be used on the double-ended switchgear. A sync check relay (Basler BE1-25) will be connected to the line side PTs on each incoming breaker.

16.0 MV MOTOR CONTROL CENTER MOTOR

The medium voltage motor control center (MV MCC) will be indoor, arc resistant Type 2 per IEEE C37.20.7. Power bus will be copper and will be insulated with flame retardant, non-hygroscopic insulation.

The 4 kV motors, 2500 HP and below, will be fed from medium voltage controllers using fused controllers, type NEMA E2 with vacuum contactors and a microprocessor based motor relay (SEL 710) with a communications port connected to the DCS. Motor RTDs will be wired to the motor relay.

Each motor feeder will be electrically operated and remotely controlled from the DCS through the protection system. The motor protection device will be used to provide metered data to the DCS.

17.0 480 V SWITCHGEAR

The low voltage switchgear will be indoor, metal enclosed switchgear, arc resistant Type 2 per IEEE C37.20.7. Power bus will be copper and will be insulated with flame retardant, non-hygroscopic insulation.

Each breaker will be electrically operated and remotely controlled from the DCS.

Each 480 V main breaker will have a power measurement ION 6200-EP1 display meter with a communications port connected to the DCS.

Each low voltage breaker will have adjustable long time and short time trip elements with three-phase current indication. Ground and instantaneous protections are not required.

A manual bus transfer scheme with make before break circuitry with momentary paralleling of the unit two auxiliary transformers will be used on the double-ended low-voltage switchgear. A sync check relay (Basler BE1-25) will be connected to the line side PTs on each incoming breaker.

18.0 LV MOTOR CONTROL CENTER

LV Motor controllers will be metal enclosed, freestanding, dead front, NEMA 1 type motor control centers with NEMA Type B wiring. Power bus will be copper and will be insulated with flame retardant, non-hygroscopic insulation.

Circuit breakers will be 3 pole, rated 600 Vac, 100 A minimum frame size, with interrupting rating equal to the short circuit bracing of the main bus. Motor circuit protector for motor starters will be molded case type and will have adjustable magnetic-only trip units. Feeder breakers will be molded case type with thermal-magnetic trip units.

Controllers for low voltage three-phase motors will be the combination type consisting of a motor circuit protector (MCP) and a magnetic contactor with an electronic overload relay.

A 480-120 volt control power transformer (CPT) will be supplied for each combination motor starter and lighting/heating controller. CPT will be provided with additional volt ampere (VA) capacity for space heater power for motors 30 HP and larger. The CPT will not be less than 50 VA.

Combination motor starters and lighting/heating controllers, NEMA Sizes 1 through 4, will be of plug-in type. The minimum contactor size will be NEMA Size 1.

LV MCCs for 200 HP and 250 HP motors will use soft starters instead of contactors.

Lighting and heating controllers will be similar to combination motor services except that overload relays will not be provided and the circuit breaker will be thermal-magnetic type. A hand-off-auto (or on-off) switch will be mounted on the door.

19.0 UNINTERRUPTABLE POWER SYSTEMS

UPS systems will have a single-phase inverter sized for the maximum operating load. The inverter will be fed from the switchgear 125 Vdc batteries.

A static switch and manual by-pass switch will be located in the inverter cabinet.

Two alternate source transformers will be provided: (1) one for the inverter bypass source, and (2) one for the back up power supply source. The DCS loads will be normally fed from the UPS backed essential panel board. The DCS back up power supply is from a panel board fed from a normal alternating current source.

20.0 UNINTERRUPTABLE POWER SYSTEMS DISTRIBUTION PANELS

UPS distribution panels will supply the DCS and instrumentation power supply loads.

21.0 125 VDC SYSTEMS

125 Vdc battery systems using flooded (watering type) batteries will be sized to provide 125 Vdc power per the required load profile.

The UPS load on the batteries will have a load profile duration of 30 minutes for safe plant shutdown. Note that in the event of a utility grid failure, the essential service diesel generator will be able to supply power to the UPS isolation transformers in less than 30 minutes.

Dual battery chargers, sized to recharge a fully discharged battery in 24 hours, will feed each battery.

The batteries will be located in a separate battery room. The battery room will be provided with sufficient ventilation to prevent the accumulation of an explosive mixture of gases.

The CTG will have its own dedicated 125 Vdc battery system located in the CTG packaged control building.

22.0 STANDBY DIESEL GENERATORS

Two 480 V, 60 Hz, 3-Phase, 1,500 kilowatt electrical (kWe), 0.8 power factor (PF) standby diesel generators (DG) in outdoor enclosures will be connected to the 480 V switchgear to supply essential service power to critical lube oil and cooling pumps, gasification and auxiliary steam systems, gasification quench system, station battery chargers, UPS, heat tracing, control room and emergency exit lighting, and other critical power plant loads.

A local control panel (LCP) will be located on base with standard microprocessor based engine and generator controls, interlocks, metering, alarms, and synchronizing system. Remote control of the diesel generator will be from DCS operators via a fiber optic cable to seller’s control system.

23.0 CABLES AND WIRING – GENERAL

The allowable ampacity of power cables will be in accordance with ICEA and NEC requirements.

Cables installed in cable trays will have insulation and jacket materials which have non-propagating and self-extinguishing characteristics to minimize possible damage caused by cable fires. As a minimum, these cables will meet IEEE 383 flame test requirements.

Lighting and receptacle wiring inside buildings will be type THWN-THHN.

All control panel wiring will be insulated with 600 V NEC-type SIS insulation and all panel wiring will have wire numbers for identification.

24.0 MV CABLE

Medium voltage cable will be rated 15 kV or 5 kV, 105ºC, stranded copper conductor, ethylene propylene rubber (EPR) insulation (133% level), copper tape shield, and an overall poly vinyl chloride (PVC) cable jacket. Multi-conductor medium voltage cable will include a bare copper ground wire. MV cable shields will be grounded at the source end.

24.1 LV Power and Control Cable

Single conductor low voltage power cable will be of the following types:

- 1/C 600V, XHHW-2, cross linked polyethylene (XLPE) insulation (for lighting conductors in conduit outdoor)
- 1/C, 600V, EPR insulation; PVC Jacket – "For CT Use" (Or non-jacketed FR-EP with appropriate UL Flame test "For CT Use"): 1/C #1/0, 1/C #2/0, 1/C #4/0, 1/C 250 thousand circular mil (kcmil), 1/C 350 kcmil, 1/C 500 kcmil, 1/C 750 kcmil
- Single conductor wire and cable will be rated 600 V, 90ºC, and will have XLPE or EPR insulation. Single conductor 600 V tray cable greater than #1/0 AWG will have XLPE or EPR insulation with a PVC cable jacket rated for CT use. Non-jacketed flame retardant ethylene propylene (FREP) insulation with appropriate UL flame test may also be used for large single conductor cables.

Multi-conductor low-voltage power cable will be of the following types:

- 600V, XHHW-2, XLP or EPR insulation; PVC jacketed overall, 3/C # 8 and larger, power cable with copper equipment grounding wire sized per NEC requirements (TC rated).

Multi-conductor control cable will be of the following types:

- 600V, XHHW-2, XLP or EPR insulation; PVC jacketed overall, multi-conductor control cable (TC rated): #10 AWG, #12 AWG, #14 AWG. Multi-conductor cable conductor identification will be in accordance with Table E-2 of NEMA WC 57 (ICEA S-73-532).

24.2 Instrument Cable

Single pair instrument cable will be rated 600 V, XLPE insulation, twisted shielded pairs with drain wires and a PVC cable jacket. Conductor size will be No. 16 AWG stranded for single pair.

Multi-pair instrument cable will be rated 600 V, XLP insulation, twisted shielded pairs, or triads as required, drain wires, overall shield, and a PVC cable jacket. This type wire will be used for both low-voltage alarm and instrument (milliamp) circuits, and RTD-type signal (three wire signal). Conductor size will be No. 18 AWG stranded for multi-pair and multi-triad cable.

Single pair thermocouple extension cable will be solid alloy conductor with flame retardant XLP insulation, twisted and shielded with drain wire, and a PVC jacket. Solid alloy wire No. 16 AWG will be used for single pair.

Multiple pair thermocouple extension wire will solid alloy conductor with flame retardant XLP insulation, with each pair identified, twisted and shielded pairs with drain wire and overall PVC jacket. Extension wire will be colored, matched and calibrated to ANSI C96.1 for standard limits of error for this type of wire. Solid alloy wire No. 20 AWG will be used for multi-pair cables.

25.0 SIGNAL SEPARATION

The conduit and tray separation and minimum spacing requirements for parallel runs will generally follow Table 2 of the Process Industry Practice PIP PCCEL001.

26.0 LIGHTING

The lighting system will be designed in accordance with IESNA and API RP540, Electrical Installations in Petroleum Processing Plants illumination level recommendations with 0.8 maintenance factor. The Illuminating Engineering Society (IES) Lighting Handbook-Application Volume, Section 9, will be used for additional information on illumination levels for different process, non-process, and building areas.

Outdoor lighting will be sodium vapor fixtures controlled by photocells.

Self-contained battery backed emergency lighting and exit signs will be furnished to provide personnel egress from buildings during a total loss of plant power.

Emergency lighting will be designed to maintain the necessary illumination for a minimum of 90 minutes.

Plant perimeter roadway lighting will be included.

Illumination levels will be measured horizontally at floor or grade level. IES recommended methods of calculation and maintenance factor will be used. Maintained in-service lighting levels will be as follows:

LOCATION	FOOTCANDLES (fc)
Control Room	50
Process Area	15
(Outdoor) Operating Switchrooms	50
Stairways and Ladders (active)	5
General Outdoor Area	2

27.0 RECEPTACLES

All 120 V outdoor receptacles will be fed from ground fault circuit interrupter (GFCI)-type receptacles. All 120 V receptacles will be located so equipment at grade can be reached with a 75-foot extension cord.

Welding receptacles will be located within maintenance areas so that equipment can be reached within 100-foot radius.

28.0 GROUNDING

The grounding system design will be per IEEE-80 guidelines.

A copper grounding grid consisting of driven ground rods interconnected by bare #4/0 AWG copper conductors to form a complete grounding system for the power plant will be installed.

Grid interconnection will be using exothermic welding or approved compression connectors.

Fences will be grounded at every other post.

29.0 LIGHTENING PROTECTION

Lightning protection, where required, will be provided in accordance with NFPA 780 and UL 96. Lightning protection will not be required on metal tanks and stacks.

30.0 CONDUIT

Underground conduits will be PVC schedule 40. Conduit risers and elbows will be PVC.

Aboveground conduit will generally be rigid galvanized steel (RGS). Aluminum, PVC schedule 80, or PVC-coated conduit may also be used in corrosive areas. Aboveground conduit will be ¾ inch minimum except ½ inch conduit may be used to connect to instruments or devices with ½ inch nipples as required.

Electric metallic tubing may be used only for indoor lighting in offices, control rooms, and where the conduit is not subjected to physical damage.

Connections to equipment requiring removal from service or subjected to vibration or movement will be made with flexible conduit. Liquid tight flexible metal conduit and approved fittings will be used for outdoor and indoor equipment.

Conduit and fittings in hazardous areas will be suitable for the service.

31.0 CABLE TRAY

Cable tray will be per NEMA Standard VE-1.

Cable tray will generally be aluminum ladder-type. Channel tray will generally be ventilated aluminum-type. Solid bottom galvanized steel cable tray with covers will be used, where necessary.

Tray covers will be used, where necessary, to protect cables from physical damage.

32.0 TELEPHONE

The plant telephone system will consist of a main telephone board located in the Administration Building to allow the telephone company to install and terminate their main telephone cable. Telephone outlets will be distributed throughout the plant buildings and PDCs.

33.0 SECURITY SYSTEM

A motorized operator will control the main gate. The main gate operator will include inputs from control room and receptionist switches, exit loop, and a local keypad or card reader station.

An intercom system will be provided to allow voice communications between the main gate and the control room and receptionist area.

34.0 HEAT TRACING SYSTEM

A heat tracing system will be provided as required for process heating shown on the P&IDs and as required by the heat tracing criteria.

The heat tracing will consist of self-regulating heat tracing cable (for temperatures below 250°F), mineral insulated (MI) tracing (for temperatures above 250°F), thermostats, heat tracing panels with main contactor, and circuit breaker panels.

Heat trace monitoring will be a microprocessor based multi-point module installed in the heat trace panel board with branch circuit breaker voltage monitoring of each heat tracing circuit. The monitor will have RS485 communications to the DCS.

35.0 MOTORS

The plant motors will be in accordance with the following Standards:

- Medium voltage synchronous motors will be per API-546
- Medium voltage induction motors will be per API-541
- Low voltage induction motors below ½ HP will be 115 V, 1-phase per NEMA MG-1
- Low voltage induction motors ½ HP through 250 HP will be 460 V, 3-phase per NEMA MG-1 and IEEE 841

All synchronous motors will be rated 1.0 power factor and will have a power factor controller to maintain 1.0 power factor at all load levels.

All motors will be premium or high efficiency motors.

Motor enclosures for 460 V and 4,000 V motors below 2,000 HP will be totally enclosed forced (TEFC). Motors 2,000 HP and larger will be totally enclosed water to air cooled (TEWAC).

All 4 kV and 13.2 kV motors will have, at a minimum, Class F insulation limited to an allowable Class B temperature rise. All 4 kV and 13.2 kV motors will be capable of starting at 80 percent of motor rated nameplate voltage.

Motors rated 460 V, 200 HP or greater, will be designed for a minimum terminal voltage of 85 percent rated motor voltage during starting. All other 460 V motors per NEMA MG-1, should start and accelerate its load at a minimum terminal voltage of 90 percent rated motor voltage.

Motor nameplate HP ratings will be determined by multiplying the maximum load driven equipment brake or shaft HP by the following minimum sizing factors: For low voltage motors below 25 HP use a factor of 1.25, for low voltage motors 30 HP to 250 HP use a factor of 1.15, and for medium voltage motors use a factor of 1.1.

The 460 V motor service factor will be 1.0 and medium voltage motor service factor will be 1.0.

Motors 30 HP and larger will have space heaters.

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Appendix B-5

Control System Engineering

APPENDIX B5
CONTROLS SYSTEMS DESIGN CRITERIA
TABLE OF CONTENTS

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1.0 INTRODUCTION

Control of the design, engineering, procurement, and construction activities on the Project will be completed in accordance with various pre-determined standard practices and Project-specific programs/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 document is to summarize the codes and standards and standard design criteria and practices that will be used during the Project engineering, design, and construction phases of the Project. These criteria form the basis of the design for the control systems components and systems for the Project. More specific design and construction-related specifications and criteria will be developed during detailed design to support equipment procurement and construction.

The following design approach outlines the engineering design services by Controls Systems Engineering Group. The design will include required system architecture drawing.

The design of the Plant Control System will require the integration of many available technologies related to sensors, control elements, and plant data acquisition and control. It is intended to assemble the total system so that the plant operations personnel will have the best control and monitoring capabilities available with modern technology. The plant will be designed around a distributed control system (DCS) supported by auxiliary systems to allow the plant personnel to analyze plant conditions and react to upset conditions within the shortest period of time. This will be accomplished by providing support systems, which can simulate and predict events in advance of a process upset and alert the operator of the impending condition so action can be taken. Field sensors will be provided to monitor operation data to support the simulation programs as well as normal process information that is displayed to the operators. Multi-level system architecture will be provided with security levels between each level in order to prevent accidental manipulation of plant operations (see attached Block Diagram). Plant control will be achieved mainly in the central control room.

2.0 REFERENCES AND STANDARDS

The Project will develop detailed project specific practices and procedures during detailed design. The Project practices and procedures will be developed from the owner's engineering technical practices. The owner's engineering technical practices incorporate the following industry standards with additional guidance based on the owner's experience:

- ANSI/ISA-84.00.01-2004: Functional Safety: Safety Instrumented Systems for the Process Sector
- ISA RP 60.3 Human Engineering for Control Centers
- ISA RP 60.7 Control Center Construction
- ISA S71.04 Environmental conditions for Process Measurement and Control Systems: Airborne Contaminants
- API RP 554 Process Instrumentation and Control
- API RP520 PT II: Sizing, Selection, and Installation of Pressure Relieving Devices in Refineries
- API RP 556: Instrumentation and Control Systems for Fired Heaters and Steam Generators
- IEC-61508: Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
- NFPA 75 Standards for Protection of Data Equipment.
- NFPA 101 Life Safety Code
- NFPA 85: Boiler and Combustion Systems Hazards Code – 2007 Edition
- NFPA 72: National Fire Alarm Code – 2007 Edition
- NFPA 70: National Electric Code – 2008 Edition
- Electrical equipment and components to be purchased will include third party approvals from UL, FM, or CSA as required.

3.0 CENTRAL CONTROL

Control center size will be determined by the number of process units to be controlled, the number of operators required to control the units, a minimum complement of supervisory/technical personnel, and the amount of equipment within the building.

Equipment housed in a CC typically includes the following:

- Field Termination or marshalling cabinets
- Process Automation System (PAS) equipment, including consoles, I/O racks, communication racks, support equipment required by technical or maintenance personnel.
- Communication systems, including but not limited to Public Address (PA) or paging systems, VHF/UHF radio systems, telephone equipment, general purpose communications associated with Ethernet or similar communication networks, and so on.
- UPS equipment, batteries, associated switchgear, breaker, electrical panels, transformers.
- Machinery condition monitoring systems.
- HVAC and air purification equipment.

- Computers used directly for control or management of the process.

3.1 Operator's Work Stations

The system operator interface or HMI will be a microprocessor based workstation (or workstations) with a state of the art object based graphical user interface. The HMI software typically includes the following HMI displays and functions:

- Menu/navigation displays
- Configuration displays
- Alarm summary display
- Event summary display
- Operating group displays
- Trend displays
- Loop tuning display
- System status display
- Diagnostic and maintenance displays
- Point detail displays

Collected data will be available for use in operator trend displays, custom displays, reports, application programs, spreadsheets, and ODBC compliant databases. The system will include built in reporting functions, such as alarm/event log, alarm duration log, integrated Excel reports, downtime analysis, free format reports, point cross reference report, and ODBC data exchange reports. Support for generation of periodic, demand, and event driven reports to screen, printer, file, or directly to another computer for analysis or viewing electronically will be included.

3.2 Alarm Management

The system will be capable of monitoring the process signals for out of normal conditions as set by the plant supervisory personnel. When detected, an alarm condition will be presented to the operator for proper action. In addition, all alarms will be given a priority level, so that the operator can respond to the more serious conditions first. Each alarm will be time stamped, logged on the alarm recorder, and stored in the system historian to be available for analysis. The system will also be supplied with Sequence of Events capability in order to be able to identify first out events when serial conditions need to be documented.

3.3 Report Generation

The capability to develop useful reports for both the operations and supervisory personnel will be included in the system. These reports will be of the repetitive type, as well as, special reports generated to support short-term goals or testing programs.

3.4 Optimization

This function will allow the plant supervisory personnel to develop control schemes to enhance the overall safety, efficiency, and emissions parameters of the plant operations. This development work will normally occur utilizing the plant data but in an off-line mode until the techniques are fully developed and tested so that implementation is completed in a safe manner.

3.5 Support Work Stations

Work stations will be provided to support software development and testing, report generation, optimization and advanced control, as well as engineering work stations to allow for system troubleshooting and configuration changes to the system without interfering with the operation of the plant.

3.6 Firewalls

Prevention of access to the direct plant controls by unauthorized individuals will be provided to provide a high level of security to the operations. These firewalls will be provided between each level of the overall system.

3.7 Outside Communications

Capability to communicate with parties outside of the plant will be provided at the highest level of the system. These typically include owner employees that are not located at the Project Site, but may include suppliers of goods and services, and outside parties and suppliers of equipment for maintenance purposes. This firewall will be supplied with a very secure firewall protocol.

3.8 Support Equipment

The control building will be equipped with uninterruptible power systems (UPS) to maintain the operation of the control system during power outages. Also the building will be provided with a very complete fire detection, alarm, and response system.

4.0 REMOTE DATA ACQUISITION AND CONTROL

To acquire the plant information and deliver the control signals to the final control elements, remote hardware will be supplied. It will be housed in instrument shelters located at or near the process units or equipment areas and will be connected to the central control system by redundant fiber optic data highways. This hardware will be capable of acquiring analog data in the form compatible with the field instrumentation and delivering analog control signals to final control elements such as control valves. In addition, digital inputs that depict status of equipment and digital outputs usually applied to on/off control, are processed by this type hardware. Sequence of Events processing is also included in this area.

4.1 Programmable Logic Controllers (PLC)

Programmable controllers will be applied to areas requiring standalone sequential control such as solids handling or water treating systems. These controllers will be interfaced to the central control system through direct communication channels.

4.2 Control Packages with Supplied Equipment

Certain equipment such as large compressors, gas and steam turbines, and packaged process units, are supplied with dedicated control systems that are pre-programmed to manage the startup, operation, safeguard, and shutdown of the supplied equipment. This type of system will also be interfaced to the central control system through redundant communication channels to allow the operator to be informed of the operation of the equipment as well as enter control commands. Either redundant or triple redundant controllers will be considered, depending on the critically of the application.

4.3 Safety Instrumented Systems (SIS)

The Project will implement the latest proven SIS (Safety Instrumented System) equipment as an integral part of the control system design. The design of the SIS system will comply with the Project SIS safety requirements specification. The appropriate SIL (Safety Instrumentation Level) will be determined and implemented during the detailed design stage. The SIS system will be based on a programmable technology. The operator interface will be engineered so that SIS information is available through the operator display. ESD (Emergency Safety Device) buttons in the control room will be connected through a safety-approved redundant link to the remote equipment rooms.

The SIS system will provide sequence of events recording. The interface to this event log will be common with that of the DCS and the SIS will be time synchronized with the DCS.

All transmitters connected to the SIS system will be of the intelligent type and a method of “stripping” off maintenance data will be provided. Options to generate discrepancy alarms between the control and SIS signals for the same service measurement will be investigated during detailed design.

4.4 Fire and Gas System

Dedicated SIS processors will be provided for fire and gas detection and alarming. The operator interface to the fire and gas system will be via the operator displays in the central control room. The field signals will be gathered in the remote equipment rooms and data will be transmitted to the SIS.

Fire detection equipment for smoke detection, heat detection, manual stations, alarms, and signal monitoring and system control will be of the hard-wired addressable type which includes but is not limited to control unit, power supply, input modules, alarm modules, extinguishing system releasing modules, and auxiliary relay modules, as required, to provide the required system logic. UV/IR (Ultraviolet / Infrared) flame detection equipment will be of the microprocessor-based multi-channel type with voting logic functions.

Buildings including the central control room, power distribution centers, and remote control equipment, should be fitted with a high-sensitivity smoke detection system for early warning. These systems will detect fire before visible smoke or fire is present.

5.0 FIELD INSTRUMENTATION

5.1 General

All instrumentation, with the exception of valve actuators and local indicators, should be electronic. The use of local pneumatic controllers will be avoided.

Instrumentation selection will restrict the use of mercury-containing substances.

Dedicated field instruments will be used for SIS applications. Adequate redundancy will be provided as required to meet the requirements defined by the loop integrity level and plant reliability requirements.

Switches will not be used in SIS applications where transmitters are available as an option for a measurement signal.

The use of local gauges (temperature, pressure, level, and flow) will be minimized through the use of local liquid crystal display (LCD) readouts on transmitters.

Instruments will be, wherever possible, close coupled and impulse tubing minimized. Instruments should be located in areas with easy access (such as walkways, permanent platforms, or at grade).

Technologies that would lead to minimizing on-site calibration of the instruments will be considered.

Wireless transmitters may be used where appropriate and in non-critical applications.

5.2 Final Control Elements – Valves

All instrument valves will comply with the Project fugitive emissions requirements.

Valves with double acting actuators (no spring) will have an associated interlock configured such that the valve is moved to the safe position on low instrument air pressure. This interlock will generally be configured in the DCS unless the duty demands use of the SIS system.

Options to obtain and utilize control valve signatures will be investigated during the design.

5.3 Cables

Instrumentation cables will be aboveground and use steel wire armor (SWA) for mechanical protection. Fiber optic cables for network connectivity may be used between the remote areas and the central control buildings with route diversity.

Fiber optic cables meant for control-related use will have dedicated patch panels to separate them from general-purpose telecommunication patch panels. The control-related fiber and related equipment will be uniquely marked by color and by tagging convention. Additional protection will be considered during design.

SIS cable and wires will be different color and tagged/labeled to distinguish it from normal control wiring. SIS junction boxes will be separate and labeled to identify contents as relating to SIS.

5.4 Vibration Monitoring

Vibration monitoring equipment will be supplied on all major rotating equipment. A central condition monitoring system may be provided to make the design "best in class" and to help minimize the life cycle costs for the plant.

5.5 Development Technologies

There are a number of developing technologies that will become accepted practices in the next few years. Foundation fieldbus is an example. Foundation fieldbus has been accepted in many areas of control and its presence is increasing notably in the process industries. Therefore, during the detailed design phase, some of these technologies will be evaluated and may be applied if the technology presents an advantage in safety, reliability, or cost.

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