

**Appendix B**  
**Design Criteria – Engineering Construction Specifications**



**Appendix B1**  
**Civil Engineering Design Criteria**



**APPENDIX B1**  
**CIVIL ENGINEERING DESIGN CRITERIA**  
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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 design for site preparation, 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 summarizes the applicable codes, standards, laws and ordinances and Section 3 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 (USEPA), 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.

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### 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 that is more than three stories high or equivalent.
- State of California Department of Transportation (Caltrans), Standard Specifications.
- State of California Department of Water Resources, Encroachment Permit required for any activity that is within 1 mile of a State Water Project facilities, June 2005.
- 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, 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.
- Kern County Development Standards, Standards for Drainage

### 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), National Bureau of Standards (NBS).
- 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).

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- 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 Uniform Plumbing Code (UPC).
- 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. 28067571). The report is included in Appendix P as part of this submittal. A detailed geotechnical investigation will be conducted during the subsequent detailed engineering phase.

The Project Site is relatively flat, and is currently developed as agricultural fields with irrigation and drainage canals and ditches running through the property. The general site elevation varies slightly from the high point grade elevation of 288 feet, North American Vertical Datum 1988 (NAVD88). The Project Site covers approximately 473 acres, about half of which will be occupied by the main process plant areas and buildings. The unused portion of the site disturbed during construction will be returned to its pre-existing condition after completion of the site work. The historic high groundwater level is below 35 feet from existing grade at the lowest point. The Project Site is immediately underlain by approximately 10 feet of fine grained soils comprised of predominately clays and silty clays. Below the 10-foot level, the soils consist of granular material to a maximum explored depth of 100 feet below the existing ground surface.

##### 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 detailed geotechnical investigation report.

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### 3.2 Design Loads

Design loads for structures and equipment foundations are discussed in Appendix B2, 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, and culverts will be designed for AASHTO HS-20 truckloads. 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 recommendations.

### 3.3 Project Site

#### 3.3.1 Project Site Arrangement

The Project Site arrangement will conform to applicable LORS. The principal 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 systems will be provided as needed for construction, operations, maintenance, access, 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 private sanitary sewage 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 plant operation purposes.

Project Site infrastructure will conform to the following criteria:

- Site surfaces will be designed and graded to promote positive site drainage.
- Roads will be designed and installed for ease of construction and operational access purposes.
- Oil and chemical storage areas will be designed and constructed to contain potential spills.
- Storm drainage collection systems will be designed and installed.
- Sanitary sewer collection and a private onsite sewage disposal system will be designed and installed.
- Locations and requirements for site security fencing or walls, as appropriate, will conform to local laws and regulations.

#### 3.3.2 Project Site Survey Control

A topographic mapping survey was completed for portions of Sections 9, 10, and 15, Township 30 South, Range 24 East, Mount Diablo Principal Meridian, Kern County, California

dated February 9, 2009. The Project Site is located in Section 10. 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 GDEC P541 and P563. The vertical datum is the North American Vertical Datum of 1988 (NAVD 88).

### 3.3.3 Project Site Preparation

Project Site preparation will consist of clearing, stripping, and grubbing and excavating or filling soils to design grades and elevations. 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 and disposed of at an approved disposal facility in accordance with applicable LORS. Topsoil, where present, will be stockpiled at a designated onsite location for future landscaping purposes. Temporary construction laydown, access roads and parking areas will be graded and surfaced. These areas will be later returned to their pre-existing conditions at the completion of construction. Temporary and/or permanent site fencing will be installed to secure the site. Drainage, erosion and dust control measures will be implemented to control the release of dust and sediment from the site.

### 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 and/or earthen berms will be stored in stockpiles or placed at designated locations using proper erosion protection measures. Excavated material that meets the suitability requirements stipulated in the geotechnical investigation reports will be used as general site fill. Excavated material may also be used for earthen berms. 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 Occupational Safety and Health Administration (OSHA) regulations.

### 3.3.5 Grading and Embankments

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. Graded areas will be smooth, compacted, free from irregular surface changes, and sloped to drain. Cut and fill slopes and embankments will be designed to be stable and capable of carrying anticipated loads from either equipment or structures.

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

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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, as a minimum, to the grades and densities recommended in the geotechnical investigation report (Appendix P).

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 operations.

The subgrade (original ground), subbases, and base courses of roads, as a minimum, will be prepared and compacted in accordance with recommendations contained in the geotechnical investigation report (Appendix P). Compaction testing will be in accordance with ASTM standards. Uncompacted topsoil will be placed in areas to be seeded or otherwise landscaped.

#### **3.3.7 Project Site Drainage**

Storm water runoff from the Project Site will be contained onsite. The Project Site drainage system will be designed to comply with all applicable LORS.

The design of the drainage system within each process unit area is dependent on whether process solids (e.g., petroleum coke, coal, fluxant, or gasifier solids) are present.

Drainage within the gasification process and storage areas (where process solids are present) will be collected and conveyed to the solids handling water collection facility, where most of the solids will settle out. Water recovered by the solids handling water collection facility can be reused as makeup to the gasification grinding system or processed by the gasification water treatment system and recycled. High carbon content solids, such as those containing petcoke or coal, will be recycled as feedstock to the gasification system. High ash content solids will be concentrated with other gasification solids for offsite disposal in accordance with applicable LORS.

Drainage from remote solids handling areas where distances are prohibitive for gravity flow will use collection sumps for settlement of solids. These areas include Feedstock Truck Unloading, Inactive Feedstock Storage, Active Feedstock Silos, Crusher Station, and Truck Washes.

Drainage within process areas where 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 pumped or gravity trunk interceptor pipeline. Runoff during initial rainfall periods 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 initial period will be directed to a storm water retention basin. A

separate retention basin will be constructed for the Acid Gas Recovery Unit for secondary containment purposes in the event of a possible chemical spill within this unit.

Drainage outside of process unit areas but within the main plant area will be accomplished through surface (sheet) flow wherever practical. The surface drainage system will consist of mild slopes, drainage swales, and ditches to intercept sheet flow. Graded surfaces will slope away from buildings and structures at a minimum grade of 2 percent. A storm water collection system with inlets and underground piping will be provided in areas where swales are not feasible. This drainage will be directed to the process area retention basin by way of the process area underground piping system.

Runoff from undisturbed areas located within the Project Site and outside the main plant area, as well as temporary use areas returned to their pre-existing condition after construction, will surface flow to the nearest plant storm drainage interceptor ditch or swale. These drains will be designed to convey excess surface runoff to storm water retention basins located throughout the Project Site. This system will consist of drainage swales, ditches, culverts and/or underground piping where necessary.

The existing drainage patterns outside the Project Site will remain undisturbed. Excess offsite surface runoff will be directed around the Project Site according to the existing drainage patterns. Existing drainage ditches currently located at the site property boundary will be improved where necessary to prevent damage to the Project from offsite runoff.

Runoff from possible oil and chemical use areas, such as transformer areas and chemical storage areas, will be contained. Storm water collected in these 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 Ditches*

Drainage swales and ditches in unpaved areas of the process units will be sized to convey the Intermediate Storm Design Discharge (ISDD), commonly referred to as the 10-year rainfall runoff flow in accordance with the Kern County Development Standards pertaining to Drainage. Building and equipment elevations will be located above the 100-year flood level.

Erosion protection for swales and ditches will be provided where peak runoff velocities may be excessive. These swales and ditches 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 (RCP), corrugated high-density polyethylene (HDPE) pipe or corrugated metal pipe (CMP). Culverts will be sized to convey the ISDD (10-year rainfall) storm flow without exceeding the soffit of the culvert. Culvert capacity will be checked to convey the 50-year storm flow without the headwater overtopping the base of the road or top of embankment.

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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 ISDD storm (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. Pipes will be designed to limit flow velocities to a maximum of 8 feet per second (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 runoff from within the main process plant area will drain to a storm water retention basin. The storm water retention basins will be sized in accordance with the Kern County Development Standards pertaining to Drainage. The retention basin will be an excavated structure containing an impermeable liner. Water that accumulates in the storm water retention basin will be treated and reused as cooling water make-up, gasification water makeup or treated within the gasification water treatment system.

Storm water runoff from outside the main process plant area will drain to separate storm water retention basins. Retention basins will be excavated below grade and will be unlined to allow percolation of accumulated runoff into the underlying soil layer.

#### **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, black water handling, gasifier solids temporary storage, and inactive feedstock storage. The various collection facilities will be constructed of concrete, and will provide for mobile equipment access to remove accumulated solids. Water that accumulates within the solids handling collection facilities will be reused as makeup to gasification, treated within the water treatment system, or reused as feed to the ZLD unit. High carbon content solids, such as petcoke or coal, will be recycled as feedstock to the gasification system. High ash content solids will be concentrated to discharge as gasification solids for offsite disposal in accordance with applicable LORS.

#### **3.3.8 Erosion and Sedimentation Control**

Erosion and sedimentation control measures will be provided throughout the Project Site to retain sediment onsite. The Project Site drainage system will drain to zero discharge retention basins that will settle any remaining sediment carried by site runoff to prevent the release of sediment from the Project Site.

Vegetation will be removed as required during site clearing and grubbing operations. Preparation of the Project Site will be followed by earthmoving which will alter the site topography. 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.

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 storm water 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. Permanent plant roads will be asphalt paved. Pavement sections will be designed in accordance with the anticipated traffic conditions and the recommendations contained in the Geotechnical Report.

### 3.3.10 Fencing and Security

Chain-link security fencing will be provided around the plant perimeter and other areas requiring controlled access. Fencing heights will be in accordance with applicable codes and regulatory requirements. The main entrance to the secured area will have a controlled access gate.

### 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 additional screening.

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#### 3.3.12 Sanitary Waste System

Sanitary sewage will be conveyed by an underground gravity collection system and discharged to a private (onsite) sewage disposal system consisting of a conventional septic tank and leach field. The design of the sanitary sewage system will be in accordance with applicable local, state and county codes, including, specific LORS, and the Uniform Plumbing Code.

The total quantity of flow used in sizing the sewage disposal system will be calculated based on a plant population of 100 persons discharging 35 gallons per person per day. Pipe sizing and slope will be in accordance with the Uniform Plumbing Code.

**Appendix B2**  
**Structural Engineering Design Criteria**



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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 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 summarizes the applicable codes and standards and Section 3 includes the general criteria for natural phenomena, design loads, building system, and concrete and steel design. Section 4 describes the structural design methodology for structures and equipment foundations. Section 5 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, regulations, and standards (LORS) 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.

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- 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.
- State of California Department of Water Resources, Encroachment Permit required for any activity that is within 1 mile of a State Water Project facilities, June 2005.
- 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), National Bureau of Standards (NBS) 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.

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- 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 B1- 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

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- 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/A615M-08 – Standard Specification Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
- ASTM A653/A653M-08 – Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the 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 Society of Nondestructive Testing (ASNT)
- 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).
- 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 a 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,  $S_s = 1.114$
- Spectral Acceleration,  $S_1 = 0.50$
- Site Coefficient,  $F_1 = 1.054$
- 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) No. 06029C2225E dated September 2008, 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.

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#### **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 that 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 that 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 §1607.9 for floors and §1607.11.2 for roofs. Live load reduction will not be permitted in areas where equipment lay down loads are considered.

All roof areas will be designed for live loads as indicated in CBC Subsection 1607.11. Roofs will also be designed for rainwater accumulation load effect of CBC §1611. 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 (TI)**

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 §1613 and spectral accelerations and site class listed in Section 3.1.4. The Importance Factor will equal 1.25.

### 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 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 load combinations specified in CBC 2007 §1605 for strength design 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

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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 a minimum depth of 1-½ 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 ¼ 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. The paint 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 pounds per square (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 Type I or II with combination of flyash.
- **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 will 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

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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 that will be used for earthquake design of building and non-building structures.

The Project is located in a high earthquake zone and structures, systems and equipment will be designed for mapped spectral accelerations for 0.2 second and 1 second given in Section 3.1.4. 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-

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frames in the short direction, braced-frames in the long direction, and by horizontal bracing in the roof steel. The building wall system will be either metal or pre-cast concrete panels.

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 used for the design of steel and concrete structures and their foundations required for supporting equipment, pipes, and buildings. Applicable loads and load combinations will be 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. Static and dynamic analysis will be performed, when applicable. Foundation design will conform to the recommendations of the Geotechnical Investigation Report developed for the Project Site.

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 be sealed by a 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 earthquakes. 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 21 miles to the west, the White Wolf Fault approximately 22 miles to the

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southeast, and the Pleito Thrust approximately 23 miles southeast 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. These are further defined in Section 5.15, Geological Hazards and Resources.

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.

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- 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 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.

**Appendix B3**  
**Mechanical Engineering Design Criteria**



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**MECHANICAL ENGINEERING DESIGN CRITERIA**  
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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 summarizes the applicable codes and standards. Section 3 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

- Occupational Safety and Health Administration (OSHA), 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

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### 2.3 County

- Kern County, California, Rules and Regulations.

### 2.4 Industry Codes and Standards

- ABMA – American Boiler Manufacturer’s Association
- ACS – American Chemical Society
- AFBMA – Antifriction Bearing Manufacturers Association
- AGMA – American Gear Manufacturers Association
- AISC – American Institute of Steel Construction
- AMCA – Air Movers Control Association
- ANSI – American National Standards Institute
- API – American Petroleum Institute
- ASCE – American Society of Civil Engineers
- ASHT – American Standards of the Hydraulic Institute
- 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 Nondestructive Testing
- ASTM – American Society for Testing and Materials
- AWS – American Welding Society
- AWWA – American Water Works Association
- CEMA – Conveying Equipment Manufacturers Association
- CGA – Compressed Gas Association
- CMAA – Crane Manufacturers Association of America
- 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
- NACE – National Association of Corrosion Engineers
- NFPA – National Fire Protection Association
- NBS – National Bureau of Standards
- NEC – National Electrical Code
- NEMA – National Electrical Manufacturers Association
- NPDES – National Pollution Discharge Elimination System
- PFI – Pipe Fabrication Institute
- PIP – Process Industry Practices

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- RCRA – Resource Conservation & Recovery Act
- SSPC – Steel Structures Painting Council, Volume 2
- TEMA – Tubular Exchanger Manufacturers Association
- UBC – Uniform Building Code
- 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 standards listed above.

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.

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### **MECHANICAL ENGINEERING DESIGN CRITERIA**

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- If a heat exchanger (or 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. Piping materials will be specified in accordance with ASME B16.5 –Pipe Flanges and Flanged Fittings.

#### **3.1.4 Cathodic Protection**

Where required, steel underground pressure piping will be cathodically protected from aboveground piping and other steel components. Above ground 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 Nondestructive 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.

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- 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 degrees Fahrenheit (°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.

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### **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 guided by API 612 and the CTG will be guided by API 616, latest editions. Dynamic compressors will be specified in accordance with API 617 – Axial and Centrifugal Compressors and Expander-compressors for Petroleum, Chemical and Gas Industry Services.

### **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 TEMA, ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest edition and addenda. Heat transfer surfaces will be designed in accordance with HTRI – Heat Transfer Research Institute requirements

### **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 Standards. The cooling towers will be field erected. Construction materials will either be wood or fiberglass. 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 B4**  
**Electrical Engineering Design Criteria**



**APPENDIX B4**  
**ELECTRICAL ENGINEERING DESIGN CRITERIA**  
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## 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, and 4.

The power plant will have a 230 kilovolt (kV) transmission line interconnection to the Pacific Gas and Electric Company (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, 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 auxiliary load 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 Administration (OSHA)

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- 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: 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**

Electrical equipment shall be designed to meet the site seismic criteria along with the maximum and minimum design ambient conditions.

Electrical equipment will be designed to satisfy seismic requirements of IEEE 693. Specifications shall include the general requirements (Annex Sections A and B), the high level of qualification, and the appropriate specific requirements (Annex Sections C-P) of IEEE 693 for the following equipment:

- 230 kV Switchyard Equipment
- Generator Step-Up Transformers
- Isolated Phase Bus

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- Generator Circuit Breakers
- Auxiliary Transformers
- Switchgear and Non-Segregated Bus
- Diesel Generators
- Medium-Voltage Motor Control Center
- 480 V Aux Transformers and Switchgear
- Station Batteries

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

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### 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 <sub>2</sub> Sync Motors with LCI Soft Starting and Turbo-expander Gen Set	13,800 V	13,800 V
ASU and AGR Sync and Induction Motors with Direct on Line Starting	13,200 V	13,800 V
MV motors 300 HP to 3,500 HP	4,000 V	4,160 V
LV motors from 3/4 HP to 250 HP including large 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 1/2 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 and seal oil pump motors and other dc motors less than 40 HP	120 V	125 Vdc
DCS instrumentation and controls	-	24 Vdc

### 7.0 POWER DISTRIBUTION CENTERS

PDCs will be prefabricated 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 MV arc resistant switchgear will have a plenum to allow for free expansion and travel of fault-generated gas and material to the outdoors. In PDCs with only LV 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 high-accuracy class current transformers rated 0.15 percent accuracy on each line exit to PG&E
- Three potential transformers rated 0.3 percent accuracy 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 230 inch creepage distances
- Porcelain-post insulators with 230 inch creepage distances
- Relay building with heating, ventilation, and air conditioning (HVAC)
- Dual 125 Vdc battery systems, including dual 125 Vdc panels

The transmission line protective relays will be microprocessor based with fiber optic communications to PG&E Midway Substation via optical ground wires (OPGW). Two separate transmission line relays with current differential functions with phase and ground back up

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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 backup 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).

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 percent (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  $2 \times 2 \frac{1}{2}$  percent
- 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 composite bushings rated 900 kV BIL with 230-inch creepage distances

- LV cover-mounted bushings for iso phase bus (IPB) flanges
- Conservator oil preservation system with bladder and silicon gel breather
- Qualitrol<sup>®</sup> oil, temp, gas accumulation alarm relays and gauges
- Sudden-pressure relay and pressure-relief device
- Transformer temperature and alarm 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 percent (ONAN MVA base)
- HV DETC, full capacity taps, plus/minus 2 × 2 ½ percent
- 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 composite bushings rated 900 kV BIL with 230 inch creepage distances
- LV cover-mounted bushings for IPB flanges
- Conservator oil preservation system with bladder and silicon gel breather
- Qualitrol<sup>®</sup> oil, temp, gas accumulation alarm relays and gauges
- Sudden-pressure relay and pressure-relief device
- Transformer temperature and alarm 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 percent (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

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- LV cover-mounted bushings for non-segregated bus duct flange
- Conservator oil preservation system with bladder and silicon gel breather
- Qualitrol<sup>®</sup> oil and temp alarm relays and gauges
- Qualitrol<sup>®</sup> sudden-pressure relay
- ANSI standard 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 percent (ONAN MVA base)
- HV DETC, full capacity taps, +/- 2 × 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<sup>®</sup> oil and temp alarm relays and gauges
- Qualitrol<sup>®</sup> 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 percent (ONAN MVA base)
- HV DETC, full capacity taps, plus/minus 2 × 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<sup>®</sup> oil and temp alarm relays and gauges
- Qualitrol<sup>®</sup> 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 percent (ONAN MVA base)

- HV DETC, full-capacity taps, plus/minus  $2 \times 2.5$  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<sup>®</sup> oil and temp alarm relays and gauges
- Qualitrol<sup>®</sup> 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 ( $^{\circ}\text{C}$ ) on the enclosure and  $105^{\circ}\text{C}$  on the conductor.

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

## 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. The power bus will be copper and will be insulated with flame-retardant, non-hygroscopic insulation.

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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 backup functions (SEL 387A).

The 13.8 kV main incoming breakers will have breaker failure protection included in the unit auxiliary transformer differential relay (SEL 387A).

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 751). 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 overcurrent relay (SEL 751).

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 lockout 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 MV motor control center (MV MCC) will be indoor, arc-resistant Type 2 per IEEE C37.20.7. The 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 MV 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. The motor-protection device will be used to provide metered data to the DCS.

## **17.0 480 V SWITCHGEAR**

The LV switchgear will be indoor, metal-enclosed switchgear, arc-resistant Type 2 per IEEE C37.20.7. The 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 LV 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**

The LV MCC will be metal-enclosed, freestanding, dead front, NEMA 1 type MCCs with NEMA Type B wiring. The 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. The motor-circuit protector (MCP) 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 LV 3-phase motors will be the combination type consisting of a 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 250-HP motors will use soft starters instead of contactors.

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Outdoor lighting 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 with 125 Vdc input and 120 Vac output. A static switch and manual by-pass switch will be located external to the inverter cabinet. UPS inverters will be located in the power block PDC and also in the control building PDC.

#### **20.0 UNINTERRUPTABLE POWER SYSTEMS DISTRIBUTION PANELS**

UPS distribution panels will supply the DCS and instrumentation power supply loads. The DCS loads will be normally fed from the UPS-backed essential panel board. The DCS backup power supply is from a panel board fed from a normal alternating current source.

#### **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 125 Vdc battery used for the STG emergency lube oil and seal oil pumps will be sized for a time duration required by the STG manufacturer. The CTG will have its own dedicated 125 Vdc battery system located in the CTG packaged control building.

The UPS load on the batteries will have a load profile duration of 30 minutes for safe plant shutdown. 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 flooded batteries will have a spill protection system and 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.

#### **22.0 STANDBY DIESEL GENERATORS**

Two 4160 V, 60 Hz, 3-Phase, 1,500 kilowatt electrical (kWe), 0.8 power factor (PF) standby diesel generators (DG) in a weather-protected non-walk-in outdoor enclosures will be connected to the 4160 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.

Each standby generator will have a class H insulation system rated 125°C at standby rating, a brushless excitation system with a PMG, and VPI insulation. Dual 12 Vdc batteries will be used to start the diesel engine.

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 that have non-propagating and self-extinguishing characteristics to minimize possible damage caused by cable fires. At 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**

MV cable will be rated 15 kV or 5 kV, 105°C, stranded copper conductor, ethylene propylene rubber (EPR) insulation (133 percent level), copper tape shield, and an overall polyvinyl chloride (PVC) cable jacket. Multi-conductor MV cable will include a bare copper ground wire. MV cable shields will be grounded at the source end. MV Cable rated 2 kV, non-shielded, single conductor cable may be used for generator dc excitation cable or used for generator excitation transformer secondary leads.

#### **24.1 LV Power and Control Cable**

Single-conductor LV power cable will be of the following types:

- 1/C 600V, XHHW-2, cross-linked polyethylene (XLPE) insulation (for lighting conductors in conduit outdoors).
- 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, 90°C, 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 LV power cable will be of the following types:

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- 600V, XHHW-2, XLPE 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, XLPE 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, XLPE insulation, twisted shielded pairs, or triads as required, drain wires, overall shield, and a PVC cable jacket. This type of wire will be used for both LV 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 XLPE insulation, twisted and shielded with drain wire, and a PVC jacket. Solid alloy wire No. 16 AWG will be used for single-pair cable.

Multiple-pair thermocouple extension wire will be solid alloy conductor with flame retardant XLPE 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 with shields to direct the light toward the ground.

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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:

<u>LOCATION</u>	<u>FOOTCANDLES (fc)</u>
Control Room	50
Process Area	15
Switch-rooms	30
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 a 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 completed using exothermic welding or approved compression connectors.

Fences will be grounded at every other post.

## 29.0 LIGHTNING 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.

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#### **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 3/4-inch minimum except 1/2-inch conduit may be used to connect to instruments or devices with 1/2-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**

The cable tray will be per NEMA Standard VE-1.

The cable tray will generally be aluminum ladder-type. The 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 freeze protection and process heating shown on the P&IDs.

The heat tracing will consist of self-regulating heat-tracing cable (for temperatures below 250 degrees Fahrenheit [°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:

- MV synchronous motors will be per API-546
- MV induction motors will be per API-541
- LV induction motors ½ HP and below will be 115 V, 1-phase per NEMA MG-1
- LV induction motors ¾ 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 LV motors 30 HP to 250 HP use a factor of 1.15; and for MV motors use a factor of 1.1.

The 460 V motor service factor will be 1.0, and MV motor service factor will be 1.0.

Motors 30 HP and larger will have space heaters.

**Appendix B5**  
**Controls System Design Criteria**



**APPENDIX B5**  
**CONTROLS SYSTEMS DESIGN CRITERIA**  
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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 the 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. The design is intended to assemble the total system so that the plant operations personnel will have the state-of-the-art control and monitoring capabilities. 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 in a timely manner to upset conditions. Multi-level system architecture will be provided with security levels between each level in order to prevent accidental manipulation of plant operations. 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:

- AGA – American Gas Association
- ANSI/ISA-84.00.01-2004: Functional Safety: Safety Instrumented Systems for the Process Sector
- CGA – Compressed Gas Association

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- 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 RP 520 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
- EEMUA - Engineering Equipment Manufacturers Users Association
- IEC-61508: Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
- FAA – Federal Aviation Association
- 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, TUV or CSA as required.

### 3.0 CENTRAL CONTROL

Control Center (CC) 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, and 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.
- Uninterruptible power supply (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 will be routine reports, 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

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### **CONTROL SYSTEMS DESIGN CRITERIA**

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development work will normally occur using 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 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 of hardware. Sequence-of-Events processing is also included in this area.

#### **4.1 Programmable Logic Controllers (PLC)**

Programmable logic 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 to enter control commands. Either redundant or triple-redundant controllers will be considered, depending on the criticality of the application.

## 4.3 Safety Instrumented Systems (SIS)

The Project will implement the latest proven Safety Instrumented System (SIS) 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 Safety Instrumentation Level (SIL) 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 Emergency Safety Device (ESD) 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.

## 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. Ultraviolet/Infrared (UV/IR) 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.

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#### **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 necessary 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.

Wherever possible, instruments will be 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 use 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 colors and will be tagged/labeled to distinguish from normal control wiring. SIS junction boxes will be separate and labeled to identify contents as relating to SIS.

#### **5.4 Vibration Condition Monitoring**

Vibration monitoring equipment will be supplied on all major rotating equipment. A central condition monitoring system may be provided to make the design “state of the art” 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.