

WATER AGENCIES' STANDARDS

Design Guidelines for Water, and Sewer Facilities

SECTION 9.1 WATER PUMP STATION DESIGN

9.1.1 PURPOSE

The purpose of this section is to provide general guidelines for water pump station design. These design criteria should be considered in the appropriate stage of the design submittals for a pipeline project.

9.1.2 STANDARD TERMS AND DEFINITIONS

Wherever technical terms occur in these guidelines or in related documents, the intent and meaning shall be interpreted as described in Standard Terms and Definitions.

9.1.3 GENERAL

It is the responsibility of the user of these documents to make reference to and/or utilize industry standards not otherwise directly referenced within this document. The Engineer of Work may not deviate from the criteria presented in this section without prior written approval of the Agency's Engineer.

9.1.4 GUIDELINES

This section covers the design of raw water, treated water, and reclaimed water pumping stations. These facilities are referred to here as pumping station(s). Raw water pump stations provide for inlet screening and the problems associated with the existence of mussels as appropriate. The DESIGN CONSULTANT's pumping station design incorporates these operational and feature guideline requirements into the project Contract Documents.

Before the design of any pumping station begins, the Agency's staff shall determine which Special Pumping Station Requirements, if any, are required in the project design.

Special Pumping Station Requirements are optional and are not required for all pumping stations. Special Pumping Stations Requirements are typically for pumping station designs with high lift or high flow pumps, special environmental concerns, or other special design requirements as determined.

At the time of the Basis of Design Report (BODR) submittal, the DESIGN CONSULTANT submits a written verification to the Agency that the design complies with the required Water Agencies' Standards and agreed design criteria. This verification can be in the form of a cover letter attached to a list of these criteria with each item to be incorporated into the design of the pumping station checked off. A notation should be made in the margin indicating the specific design submittal when the DESIGN CONSULTANT expects this item to be incorporated into the design drawings and specifications. Note: This annotation assists reviewers of design submittals. The DESIGN CONSULTANT also references and discusses any criteria in this listing to which it takes exception and does not recommend implementing. For smaller systems, the Agency may require a package type booster pump system.

9.1.5 PROJECT DOCUMENT PRESENTATION GUIDELINES

These Guidelines are intended to promote uniformity of report drawings and the Contract Documents between the various Water Capital Improvement Program (CIP) projects during the design phase of implementation.

A. Basis of Design Report Drawings:

The Pre-design Report (if one is produced) is normally developed by the Agency. The DESIGN CONSULTANT develops the BODR in accordance with Agency requirements and the Water Agencies Standards. The format requirement for preliminary drawings used in the BODR may not be required to completely match that required for Contract Documents.

B. Contract Specifications:

The DESIGN CONSULTANT shall produce Standard and Guide Specifications, necessary to meet the requirements of each project, and develops any required additional sections.

Equipment specifications prepared by DESIGN CONSULTANT avoid sole source equipment requirements and ensure competitive pricing for major equipment to be supplied by the Construction Contractor, such as pumps, motors, and emergency power generation equipment.

DESIGN CONSULTANT includes in the contract special provisions, a list of all shop drawing submittals required from the Construction Contractor for review and approval. This listing includes a reference to the specification section number and title where each item requiring review and approval is described.

The special provisions require that the Construction Contractor make submittals of proposed equipment to the Agency for approval of materials, fabrication, assembly, foundation, installation drawings, and Operation and Maintenance Manuals. Review and approval is by the DESIGN CONSULTANT or Agency staff, as determined by the Agency.

The Agency shall review all shop drawing submittals including the following major equipment: pumps; motors; valves; emergency power generation system; electrical equipment and controls, prior to their return to the Construction Contractor.

C. Contract Drawings:

The DESIGN CONSULTANT develops contract drawings to meet the needs of each project. Preliminary drawings included in the BODR, when provided to the DESIGN CONSULTANT, may be used initially as the basis of design and may be amended for incorporation into the Contract Documents. The contract drawings must conform to the requirements of the Water Agencies' Standards. The DESIGN CONSULTANT reviews the Water Agencies' Standards and changes or modifies its guidelines as necessary to meet the requirements of each project, and develops any additional details not included in the Water Agencies Standards.

9.1.6 CODES AND STANDARDS

Codes and standards to be used in the design of pumping stations include the following:

Abbreviation	Code or Standard
AASHTO	American Association of State Highway and Transportation Officials
ABMA	American Bearing Manufacturers Association
ABMA	American Bearing Manufacturers Association
ACI	American Concrete Institute
AGMA	American Gear Manufacturers Association
ANSI	American National Standards Institute
ASHREA	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
CalTrans	California Department of Transportation
FS	Federal Specifications
HYI	Hydraulic Institute Standards
IEEE	Institute of Electrical and Electronics Engineers
ISA	Instrument Society of America
MSS	Manufacturers Standardization Society, Inc.
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SSPC	Steel Structures Painting Council
UBC	Uniform Building Code
UFC	Uniform Fire Code
UL	Underwriters Laboratory, Inc.
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code
WAS	Water Agencies' Standard

Specific structural design codes and standards to be used in structural design for pumping stations are included in design guide Section 9.2.

The DESIGN CONSULTANT also observes all applicable codes and other requirements adopted by local permitting agencies. The current version of these documents effective at the time of receipt of Notice to Proceed with the design phase is used as reference for design purposes. In case of conflict between the requirements of these reference documents and any code adopted by a local permitting agency, the code requirements prevail.

9.1.7 PUMPING STATION HYDRAULICS AND PIPING

A. Station Hydraulics:

The DESIGN CONSULTANT refers to Agency Staff or Predesign Report (if one is provided) for information on system hydraulics, design capacity, system head curves, net positive suction head (NPSH), pump operating curves, piping configuration, transient surge analyses and control. The DESIGN CONSULTANT reviews this information and prepares hydraulic calculations for the BODR based on the following:

1. System head curves
2. Pump operating curves
3. Available NSPH
4. Piping configurations
5. Pump controls
6. Transient surge analyses

The BODR shall include a figure showing both the system head curve and pump operating curves as described in paragraph 9.1.8.E of this chapter. Where variable frequency drives (VFDs) are used, pump-operating curves must also indicate pump operation at various speeds.

B. Piping Materials:

All pumping station suction and discharge piping are ductile iron (DI) or engineered shop fabricated steel or as directed by the Agency. Avoid the use of pipe threads on ductile iron pipe flanges. Where the use of threaded flanges is unavoidable, the thread must be assembled with epoxy and coated on the interior and exterior as described or as directed by the Agency.

Select piping systems, which are appropriate for the type of fluid being conveyed. Prepare a piping schedule presenting materials, pressure rating, and test requirements.

For acceptable linings and coatings of pumping station piping, see subsection 9.1.20 of this chapter.

C. Flow Velocities:

The DESIGN CONSULTANT sizes suction and discharge pipe so that the maximum suction velocity is 5 fps and the maximum discharge velocity is 8 fps. The minimum recommended discharge-piping velocity is 3 fps.

D. Bolts and Fasteners for Piping:

The DESIGN CONSULTANT specifies that all bolts and pipe fasteners for exposed ferrous piping are 304 or 316 stainless steel.

The DESIGN CONSULTANT specifies that all buried bolts, pipe fasteners, flexible couplings or Dresser-type couplings, are type 304 or 316 stainless steel. All buried coupling must be wrapped with petrolatum/wax tape.

E. Dissimilar Metal/Isolation Connections:

Small piping, fitting, and appurtenances 2 inches and less in diameter connected to the pump suction and discharge piping must use PVC bushings and stainless steel pipe. Galvanized steel pipe is not acceptable.

Insulating PVC bushings and gaskets must be placed between connections of brass and ferrous piping and between any other pipes made of dissimilar metals.

The DESIGN CONSULTANT indicates any other isolation fittings required to isolate pumping station piping from sections of buried piping that are protected by a cathodic corrosion control system.

F. Fittings for Differential Settlement:

Flexible Dresser-type couplings, mechanical joints, or other flexible type fittings with restraining devices are provided where both inlet and discharge piping connect to a pumping station or valve vault wall to allow for differential settlement (avoid ball type joints as repeated surges will cause these types of joints to leak). The fittings or couplings must have a fusion bonded epoxy coating on both the inside and outside surfaces.

G. Schedule of Pumping Station Piping Materials:

The DESIGN CONSULTANT includes in Contract Documents a schedule of piping materials for all exposed and buried piping over 2 inches in diameter within the property limits of the pumping station. The schedule includes the following information:

Item No.	Diameter	Description	Units	Quantity	Remarks

9.1.8 SELECTION OF MAIN PUMPING UNITS

A. General:

The DESIGN CONSULTANT refers to Agency's Staff and/or the Pre-design Report (if provided by the Agency) for information on the preliminary selection of vertical turbine or horizontal split case centrifugal pump configuration.

Pumping systems are normally controlled by a level control system (with a set discharge storage level using constant speed pumps) or a closed zone system (where a set pressure is maintained using variable frequency drives on pumping units).

B. Selecting the Type of Units:

If Agency or the Pre-design Report does not indicate which pump configuration should be used, the DESIGN CONSULTANT presents in the BODR a comparative evaluation of cost, operability, and constructability issues. This analysis includes general arrangement drawings and cost estimates for the pumping station with various configurations. Based on this analysis and the DESIGN CONSULTANT'S recommendation on pump configuration, the Agency directs the DESIGN CONSULTANT as to which configuration to use before proceeding with final design of the pumping station.

C. Horizontal Split Case Pumps:

If horizontal split case pumps are selected for use at the pumping station, include the following features of pump construction:

1. Type: Horizontal split case.
2. Casing: Close grained cast iron tested to 150% of maximum head.
3. Impeller: Enclosed double suction, bronze, hand finished, statistically and dynamically balance and keyed to shaft.
4. Wearing Rings: Renewable, type 316 stainless steel.
5. Shaft: Type 316 stainless steel, machined and ground, designed for maximum deflection.
6. Shaft Sleeve: Type 316 stainless steel.
7. Bearing: Heavy-duty grease lubricated ball type, and double row thrust bearings. Minimum L-10 bearing life.
8. Seals: Mechanical with flushing water.
9. Shaft Coupling: Heavy-duty flexible with OSHA safety guard.
10. Base: Heavy cast-iron or steel base, with integral rim or pan and drain.

A typical pumping station general arrangement drawing for the horizontal pumping configurations is provided for the DESIGN CONSULTANT'S consideration in Figure 9.1-1.

D. Vertical Turbine Pumps:

If vertical turbine pumps are selected for use at the pump station, the DESIGN CONSULTANT includes the following features of pump construction:

1. Type: Vertical canned turbine.
2. Barrel or Can: Heavy-duty steel epoxy coated for mounting in concrete encasement, designed to support the unit without vibration at any operating speed. Barrel or can is provided by the pump manufacturer.
3. Bowls: Cast iron with amine cured epoxy coated water passages. Typically, the top of pump bowls are to be 2 feet below suction invert elevation.
4. Impellers: Cast bronze, enclosed single plane type, balanced to operate within acceptable field of vibration limits.
5. Shaft: Line shaft, type 316 stainless steel.
6. Shaft Couplings: Type 304 stainless steel.
7. Wear Rings: Bronze.
8. Seals: Mechanical with flushing water.
9. Bearings: Heavy-duty, grease lubricated, bronze. Minimum L-10 bearing life.

The pump motor coupling must allow for adjustment of the pump impeller at the upper end of the motor.

The vertical turbine pump discharge head, sole plate, column and cans are to be provided by the pump manufacturer as a package.

A typical pumping station general arrangement drawing for the vertical turbine pumping configurations is provided for the DESIGN CONSULTANT'S consideration in Figure 9.1-2.

E. Pump Operating and System Head Curves:

The DESIGN CONSULTANT prepares a combined system head curve and pump operating curve showing all pumps running, with both Hazen-Williams coefficients of 110 and 140 to determine friction loss. Curves represent both maximum and minimum pressures to be experienced by the pumping system. These curves are shown as a figure in the BODR and be repeated on the contract design drawings. When as-built drawings are prepared, the DESIGN CONSULTANT places the actual pump operating curves on the contract design drawings.

When selecting pumps, the DESIGN CONSULTANT considers the following items:

1. Select a pump-operating curve where the required operating point is beyond the minimum and near the maximum efficiency point (optimally just to the right of this point) of the pump curve.
2. Select a pump operating curve where the operating point is near the minimum value of radial thrust.
3. Avoid pumps with “flat” pump operating curves where a small change in total dynamic head (TDH) results in a large change in pump flow.
4. Specify a pump/impeller located near the center of the pump operating curve recommended operating range. To facilitate modifying the pump with a different impeller to change pumping performance. This modification may be required based on information determined during station startup operational testing when the pump is discharging into the system.
5. In specifying the pump operating point, specify an operating flow at the required head that is 105% of the design requirement to allow for loss of operating capacity from pump wear and increased pipe friction (**Design Flow = Peak Design x 1.05**).

F. Vibration and Cavitation:

To minimize vibration and resonance, the mounting pedestal, floor or inertia block must be of sufficient mass, typically 3 times greater than the mass of the pumps. The DESIGN CONSULTANT must require level installation of the pump base and anchor bolts, and dynamically balanced pumps to prevent vibration. Vibration amplitude must be less than limits set by the Hydraulic Institute standards. The DESIGN CONSULTANT selects suction and discharge piping to prevent cavitation or excessive vibration. The DESIGN CONSULTANT also selects a pump that operates within a stable operating range on pump operating curves to prevent cavitation.

G. Net Positive Suction Head (NPSH):

The net positive suction head available (NPSHA) is calculated for all pumps pursuant to standard engineering practices, less a 2-foot factor of safety. The NPSHA should always be more than the net positive suction head required (NPSHR) for the selected pump at maximum speed conditions.

H. Pump Motors:

DESIGN CONSULTANT requires pump motors with the following characteristics:

- Minimum efficiency of 93% at the specified operating point.
- Maximum rotational speed of 1800 rpm.
- Rated for 10 starts per hour.
- Nameplate horsepower that exceeds the maximum required by the pump under all operating conditions. For best efficiency, the motors specified should operate in a range within 90% to 100% of its rated power (avoid oversizing motors since efficiency and power factor drop in motors running below load rating).
- Provide a 1.15 service factor at ambient temperature plus 50°C of the nameplate voltage.
- The temperature rise rating may not exceed class "B" temperature limits as measured by the resistance method when the motor is operational at full load of 1.15 service factor continuous in a maximum ambient temperature of 40°C.
- Provide an Underwriter's Laboratory (UL) or Factory Mutual (FM) rating.
- Provide totally enclosed fan cooled squirrel cage induction type.
- Provide vertical turbine pump motors that have a hollow shaft for ease of adjustment. The Construction Contractor is required to submit a detail showing how adjustment of the pump impeller using upper end of motor is accomplished.
- The frame is cast iron.
- Windings are copper. Aluminum windings are not acceptable.
- Insulation is class "F" with epoxy coating.
- Provide heavy-duty 100,000 hour rated bearings. If bearings are oil lubricated, provide a visual oil level indicator.

- The starting code letter/locked rotor kVA shall comply with NEMA code "F" criteria or better.
- Provide an overtemperature safety switch installed in the motor windings.
- Provide a heater element installed to reduce condensation. The motor heater element is strip type that automatically disconnects when the motor starts.
- Equip with antireverse rotation ratchet. Also install a lockout limit to prevent motor start if the pump control valve is not closed.

I. Variable Frequency Drives:

Unless otherwise indicated in the Predesign Report, variable frequency drives (VFDs) are normally used on pumping units to maintain pressure on closed zone systems.

Normally when multiple pumping units are provided, the system is provided with two VFDs and the rest of the pumps have constant speed motors.

For each VFD unit, provide a manual bypass connection to allow manual across the line motor start operation (i.e., full voltage start and constant speed motor operation).

J. Hydro-pneumatic Tank/Surge Tank (Special Station Requirements):

The DESIGN CONSULTANT may consider use of a hydropneumatic tank (which provides storage for low demand periods and/or surge protection) or a surge protection tank as required in the design.

If a hydropneumatic tank or surge protection tank is used, it must include all controls and appurtenances supplied by a single vendor as unit responsibility.

A hydropneumatic tank is typically controlled as follows:

- Stage first call pump on by pump on pressure transducer or pressure switch (i.e., provide tank differential pressure transmitter to indicate tank level).
- Pump off by pump off level probe (near center of tank) or in stilling well.
- Add/vent air pressure by solenoid valves as required after each pump call cycle to obtain desired set point pressure in the tank at the pump off level.
- Low/high level probe alarms and low/high pressure switch alarms.

Alarm conditions must be telemetry alarm points. These alarm conditions also start/stop pumps and add/vent air as required to reestablish the required tank level and pressure conditions.

If used as a surge protection tank, controls include similar level probes, add/vent air pressure solenoids, and pressure switches to continuously maintain the water level near the center of the tank.

K. Pump Base Plate Installation:

Provide a detail on the drawings showing how the pump base plate is bolted to the top of the suction can for vertical turbine pumps and to the concrete equipment base for horizontal pumps.

Provide type 316 stainless steel anchor bolts, nuts and washers for securing the pump base.

L. Spare Parts and Manuals to be Supplied:

The DESIGN CONSULTANT indicates that the Construction Contractor provides the following spare parts for each size of pump installed:

- impeller
- wear ring set
- bearing set
- couplings
- mechanical seal
- set of gaskets and O-rings
- complete set of dowels
- keys and pins for fastening all parts
- complete set of any special tools required for dismantling the pump

The Construction Contractor supplies a manual for the operation, maintenance, and repair of the pump as published by the manufacturer for each size of pump installed.

M. Packaged Type Booster Pump Systems:

At the Agency's discretion, a package type booster pump system will be allowed for smaller systems. The Design Consultant shall make a recommendation to the Agency for approval. At a minimum, the packaged booster pump station shall have a built-in VFD on the motors up to 10 HP and included with a controller on motors over 10 HP.

9.1.9 PUMPING EQUIPMENT LAYOUT

The DESIGN CONSULTANT refers to the Predesign Report for any requirements for pump arrangement and/or pump spacing at the pumping station. Should the Predesign Report have no requirements, the DESIGN CONSULTANT refers to Figures 9.1-1 and 9.1-2 of this chapter. Figure 9.1-1 provides a typical pumping equipment layout for pumping stations with horizontal split case pumps. Figure 9.1-2 provides a typical pumping equipment layout for pumping stations with vertical turbine pumps.

In general, the pumping equipment layout provides convenient access for operation and maintenance personnel, equipment installation, adjustment of component parts, maintenance and equipment removal utilizing conventional general purpose tools. Equipment is arranged to provide minimum clearances on at least 3 sides. Clearances are actual to most exterior dimension, not nominal.

The DESIGN CONSULTANT allows a minimum 3-foot clearance between pump piping and appurtenances and away from all pumping station walls, stairways, ladders, etc. Placing conduit, piping panels, etc. in any designated clear spaces is prohibited. Vertical floor to overhead obstructions must be a minimum of 7 feet -6 inches. Where equipment manufacturers recommend a minimum clearance for maintenance, the DESIGN CONSULTANT provides an additional 1 foot.

For pumping stations with an electrical room and pump room in the same building, the electrical room is elevated at least 4 inches to provide positive drainage in the event of a pipe failure. The room has a window in the wall between the pump room and the electrical room for safety and to view pump operation. Provide a separate access to SDG&E meter room.

Any changes the DESIGN CONSULTANT considers appropriate to the above pump arrangement or pump spacing are presented to the Agency. The DESIGN CONSULTANT presents the agreed upon layout in the BODR.

9.1.10 PUMP INLET CONFIGURATION AND PIPING LAYOUT

A. Pump Inlet Configuration for Vertical Turbine Pumps:

If the vertical turbine pump configuration is used for the pumping station, the DESIGN CONSULTANT may use Figure 9.1-2 as a guide in configuring the inlet manifold and suction piping to each pump. Figure 9.1-2 illustrates acceptable inlet configurations for a pumping station system located inside a building and one located outside on slab. The DESIGN CONSULTANT may suggest deviations to the piping configurations shown in Figure 9.1-2 to the Agency before issuing the BODR.

B. Pump Inlet Configuration Horizontal Pumps:

If the horizontal split case pump configuration is used for the pumping station, the DESIGN CONSULTANT may use Figure 9.1-1 as a guide in configuring the inlet manifold and suction piping to each pump. Figure 9.1-1 illustrates acceptable inlet configurations for a pumping system located in a pump room below grade and in a pump room located at grade. The DESIGN CONSULTANT may suggest deviation to the piping configuration shown in Figure 9.1-1 to the Agency before issuing the BODR.

C. Pump Discharge Header Configuration Vertical Turbine Pumps:

If the vertical turbine pump configuration is used for the pumping station, the DESIGN CONSULTANT may use Figure 9.1-2 as a guide in configuring the discharge manifold and discharge piping from each pump. Figure 9.1-2 illustrates acceptable discharge configurations for a pumping station system located inside a building and one located outside on a slab. The DESIGN CONSULTANT may suggest deviations to the piping configurations shown in Figure 9.1-2 to the Agency before issuing the BODR.

D. Pump Discharge Header Configuration Horizontal Pumps:

If the horizontal split case pump configuration is used for the pumping station, the DESIGN CONSULTANT may use Figure 9.1-1 as a guide in configuring the discharge manifold and discharge piping from each pump. Figure 9.1-1 illustrates acceptable discharge configurations for a discharge manifold located in trench and one buried outside the pumping station. The DESIGN CONSULTANT may suggest deviations to the piping configuration shown in Figure 9.1-1 to the Agency before issuing the BODR.

E. Relief/Bypass Line to Suction (Special Station Requirement):

Install a bypass line with a pressure relief valve to relieve the discharge manifold to the suction manifold in a pump operation overpressure condition. This line must have a vacuum relief valve after the pressure relief valve. This line can also be used to recirculate fire pump test flows when appropriate or to bypass flow during system maintenance. DESIGN CONSULTANT provides for installation of the pressure relief valves and a flow meter on this line in a valve vault or aboveground to determine the amount of water being recirculated. The relief valve has a valve position limit switch to alarm in the PLC when the valve opens.

F. Bypass Line to Discharge (Special Station Requirement):

As a special station requirement, the DESIGN CONSULTANT may include a bypass from the suction supply manifold to the discharge manifold through a hydraulic check valve to protect against suction surge pressures or to supply low pressure flow in a pumping station failure. The bypass line is the same size as the suction line to the pumping station. DESIGN CONSULTANT provides for installation of a pressure gauge and air/vacuum valve on the bypass line located in a valve vault or aboveground.

G. Discharge Piping Assembly:

DESIGN CONSULTANT designs exposed pumping station discharge piping using spool sections, tie-rod restrained coupling adapters, or restrained Dresser-type couplings (not with studs). Discharge piping is fitted and connected so that no lengths of pipe are too long to remove from the pumping station building using the hoist equipment provided. Provide unions for the removal of all small piping appurtenances.

H. Pipe Restraints:

The DESIGN CONSULTANT indicates thrust “kick” braces at 90° elbows and all other bracing required to resist seismic forces, operational pressure and surge pressures on exposed piping installations. Indicate locations of thrust blocks and restrained joints in the contract drawings.

The DESIGN CONSULTANT designs all piping joints and thrust restraints to withstand maximum anticipated surge pressure. Base elbow fittings are not designed to carry any side thrust loading. Indicate wall pipes with intermediate flanges for thrust restraint where piping enters valve vaults or underground pumping station walls.

I. Couplings:

The selection of pipe joints or couplings and the care with which they are installed are important considerations for the DESIGN CONSULTANT. Sleeve couplings, mechanical joint couplings, rubber-gasketed push-on joint couplings, field-weld joints, grooved and shouldered couplings, butt straps, and flanges are commonly used with steel water pipe. Screwed joints are used on small steel, cast-iron, bronze, stainless, etc. The DESIGN CONSULTANT may consider patented joints if the application fits the recommended use and design data from the joint manufacturer.

1. Restrained Couplings:

Flanged adapters, sleeve-type compression couplings or grooved-end couplings should be provided with a suitable harness for longitudinal restraint. For bolted flanges, the DESIGN CONSULTANT ensures that flanges of different materials and pressure classes are compatible.

2. Flexible Couplings:

On exposed piping inside the pumping station, the DESIGN CONSULTANT avoids rigid connections in flanged piping between the pump and fixed discharge manifold piping. Flexible couplings provide ease of assembly/disassembly of piping, minor adjustment in assembled piping, pump vibration isolation and strain relief at flanged fittings.

J. Pressure Gauges:

Provide a compound pressure gauge (combination vacuum and pressure) on the suction piping and a pressure gauge on the discharge pipe of each pump installed. Typical locations for these gauges are shown in Figures 9.1-1 and 9.1-2. Gauge assemblies are mounted off the piping on a separate stand to isolate the gauges from pump vibration with the following fittings connecting to the pumping station piping:

- Stainless steel nipple
- Corporation stop
- Flexible hose off the piping to the gauge mount location
- Isolation ball valve

- Air release cock
- Diaphragm seal/pulsation dampener (to prevent corrosion and pressure surges on the gauge(s), fill the diaphragm seal and gauge with glycerin and provide a fitting for refilling)
- Stainless steel gauge snubber

Gauges must have a built-in safety plug for blowout protection in an overpressure condition. Pressure transducers have a 4 to 20 mA signal output for transmitting pressure information to the pump controls and to a pressure display panel, in accordance with subsection 9.1.18 of this chapter.

K. Flow Meters:

Sufficient straight pipe runs must be provided for flow meter accuracy when designing pipe layout. See paragraph 9.1.14 G and 9.1.18 H of this chapter for flow meter criteria.

9.1.11 EXPANDABILITY

If the Predesign Report indicates that a pumping station is planned to be expanded in the future, the DESIGN CONSULTANT ensures that adequate space is provided to accommodate the installation of future equipment. The suction and discharge piping manifold is sized and arranged to accommodate future flows without having to take the pumping station out of service when expansion is required. If it appears to be impractical or not economical to construct the pumping station building to house future equipment, the DESIGN CONSULTANT presents a comparative evaluation of cost, operability, and constructability issues in the BODR. This evaluation addresses alternative means of providing the desired capacity to meet future capacity requirements. Based on this analysis, the Agency directs the DESIGN CONSULTANT before proceeding with final design of the pumping station relative to future expansion.

9.1.12 STANDBY PUMPS AND EQUIPMENT

All pumping stations are designed with one standby pumping unit having a capacity equal to the largest pumping unit in the station.

Compressed air systems for pumping stations are provided with one standby air compressor.

9.1.13 TRANSIENT SURGE ANALYSIS AND SURGE CONTROL

The DESIGN CONSULTANT performs the surge analysis and designs a surge control system in accordance with its analysis.

A. Transient Surge Analysis:

The DESIGN CONSULTANT evaluates pumping stations to determine the potential for hydraulic transients. Computer programs for transient analysis are approved by the Agency on a case-by-case basis. State-of-the-art computer programs for transient analysis such as LIQT developed by Stoner Associates, Inc., SURGE 5 developed by the University of Kentucky, NETWORK-SURGE developed by John List, or other programs approved by the Agency, are used to evaluate all transient phenomena and proposed surge control measures. Each program, including those listed above, has unique capabilities and must be assessed for each situation to make sure it can handle the complexity of the analysis involved for the particular pumping station. The DESIGN CONSULTANT obtains from the Agency any information necessary to properly evaluate transient phenomena in water pipeline(s) connected to pumping station(s) or reservoir(s) that is within the operating system but not included in the DESIGN CONSULTANT'S scope of work.

B. Surge Control:

Surge protection is normally required at all pumping stations. Surge control measures suitable for raw water and treated water pipelines are also employed for reclaimed water pipelines.

Before initiating the detailed design of pumping stations, the hydraulic transient calculations prepared by the DESIGN CONSULTANT are submitted as an appendix to the BODR together with a description of any potential for hydraulic transients and a list of steps the DESIGN CONSULTANT recommends for further action or mitigation of the hydraulic transients. Based on the contents of this documentation, the Agency directs the DESIGN CONSULTANT to design the necessary means to mitigate hydraulic transients.

Transient control measures may be considered independent of or in combination for water systems and are limited to the following:

- Water pipeline alignment revisions to eliminate potential column separation zones.
- Shaft-mounted flywheels to increase the rotating movement of inertia.
- Globe-type pump control valves on inlet or discharge pipelines. Both the valve body and flanges are rated to withstand the shutoff head of the pump or maximum surge pressure, whichever is greater. During normal starting and stopping of the pumps, each pump must start against a closed valve. The valve must open slowly to control upsurge. During the pump stopping sequence, the control system initiates closing of the valve. At the completion of the closing cycle, a limit switch confirming complete closure of the valve signals the pump to stop. During emergency power failure, the valve shall automatically close. Closure time is set to reduce surges in the pipeline. All opening and closing times are independently adjustable, with closing times initially set as recommended in the final surge analysis.
- If surge tanks on discharge pipelines are required, size the tanks to reduce incremental surge pressure increase to a maximum of 33% of the discharge pipeline design pressure depending on pipe material. The surge tank is designed, fabricated, and tested in accordance with the ASME Code for Unfired Pressure Vessels, and is equipped with a compressed air system controls to maintain the air-to-water ratio and initiate alarms. Surge tanks are equipped with level probes add/vent air pressure solenoids and pressure switches to maintain water level near center of the tank.
- Installation of a surge anticipator relief valve which senses a loss of power and/or pressure surge wave and opens on set time delay or high pressure respectively. Install piping and valves to provide pressure relief from the pump discharge side to the suction side.
- Installation of a pressure relief valve from discharge manifold to suction manifold for routine pressure rises due to rapid changes in system demand. Operation of relief valve cannot rely on a mechanical actuator or diaphragm.
- Standpipes are not permitted for surge control on Water CIP projects.

9.1.14 VALVES

A. General:

All valves are shown on the design drawings, except small valves which are part of packaged equipment or instrument systems required by the codes or indicated in the equipment specifications. The DESIGN CONSULTANT shows all valves that are normally used by maintenance personnel to isolate equipment or sections of piping, or which are used for normal operation or control procedures. All valves 4 inches and larger are numbered and a schedule for all numbered valves is prepared by the DESIGN CONSULTANT. The valve schedule is shown on the drawings and includes the valve number, pressure rating, type of actuator, type of valve, associated fluid abbreviation, and sheet number of the drawing where the valve is shown. Unless otherwise approved, all mainline valves are the same diameter as the pipeline.

The DESIGN CONSULTANT selects materials for valves to be compatible with the fluid being conveyed and conform to requirements for valves included in the Water Agencies' Standard Approved Materials List where possible. The DESIGN CONSULTANT shall choose appropriate valves so that the number of valve types in the pumping station is minimized.

B. Isolation Valves:

In general, all isolation valves are the full-resilient seated gate valves included on the Water Agencies' Standard Approved Materials List. Subject to approval by the Agency, butterfly valves conforming to AWWA C504 may be used as an alternative to gate valves to isolate equipment.

Isolation valves are installed on the pump inlet, pump discharge line, pump manifold lines, bypass lines and surge protection line for removal and maintenance of pumps and other accessory equipment. Discharge isolation valves are installed a minimum of 3 pipe diameters downstream of pump control valves.

Buried valves are approved for buried service with a watertight bonnet and buried service actuator. Install buried valve actuator extensions, valve wells and valve frames and covers as required and conforming to Water Agencies' Standard for operation with 7-foot valve keys. All exterior valves are sited within the site security fence.

C. Pump Control Valves:

Pump control valves have an emergency shutdown power check feature for surge protection when power fails. This valve effects controlled closure when flow stops as a result of power failure before flow reversal. The flow control valve also provides pump reverse anti-rotation protection. Pump control valves are provided for controlled valve opening and closing during pump startup and shutdown. Provide a limit switch on the valve to alarm and prevent a pump from starting if the valve is open at the pump "on" call signal and also shut down the pump if the valve does not open within a specific time-delay period. Provide an emergency closing feature to close the valve at the controlled rate in the event of motor power loss. The valve should also provide for manual operation in the event of VFD equipment failure. At this time, the valve becomes a regulating valve so the pumps can operate as constant speed pumps.

During starting of the pumps, each pump pumps against a closed valve. The valve opens slowly to control upsurge. During power failure, the check feature in the valve closes automatically. All opening and closing times are independently adjustable with closing times as recommended in the final surge analysis (provide with opening and closing speed controls).

On constant speed only, pumping stations provide wide open when running globe valves.

D. Air/Vacuum Relief Valves:

Air release, air vacuum release or combination air release and vacuum valves are provided at critical locations in the pumping station piping. These valves serve to prevent small quantities of air from being captured inside the piping system, to vent large quantities of air during filling of the piping, and to prevent piping collapse because of vacuum conditions caused by rapid drainage of the piping.

Three air/vacuum relief valve configurations are used to alleviate these conditions. Air vacuum valves must be capable of venting large quantities of air while piping is being filled and allow air to re-enter while the piping is being drained. Air release valves vent accumulating air while the system is in service and under pressure. Combination air valves combine the characteristics of the two previous configurations.

These valves are placed at the end of suction or discharge manifolds or on each pump's suction or discharge pipe as required to prevent air accumulation or to provide vacuum relief.

Provide 2-inch diameter air bleeds (gauge cocks) on each pump suction line if an air release valve is not provided in the line.

On each pump discharge line, provide a gauge cock before the pump control valves and an air release valve after the pump control valve.

All air/vacuum relief valves are connected to the piping manifolds with PVC isolation bushings and stainless steel nipples and are equipped with stainless steel isolation valves and unions to allow easy removal for maintenance.

For additional Air Valve design criteria, reference design guide Section 5.5.

E. Drain Valves:

Provide a capped fitting on the suction and discharge side of each pump to drain pumps and check for residual pressure during maintenance prior to opening fittings.

F. Check Valves:

Unless otherwise required by a surge analysis, the discharge side of all pumps are provided with pump control valves in lieu of check valves as described in paragraph 9.1.14 C of this chapter.

Check valves for pumping station support systems, such as potable water or drainage systems, are heavy-duty swing type check valves with an outside spring and lever.

G. Corporation Stops for Flow Meters:

Provide 2-inch corporation stops on each pump discharge line downstream of the pump control valve for the connection of a pitot tube and/or insertion flow meter to be used for flow measurement. The corporation stops are located a distance at least equal to 8 pipe diameters downstream and 2 pipe diameters upstream of any fitting in the pipe layout which might cause turbulence. Also provide a 2-inch corporation stop on the discharge manifold before leaving the station or, if buried, in a valve vault on the discharge line to allow for measuring total pumping station flow. For flow metering devices, see paragraph 9.1.18 H of this chapter.

If the pump discharge piping arrangement does not allow for proper location of the corporation stop, provide the corporation stops for flow measurement in the pump suction line in a vault.

H. Valve Actuators:

All gate valves and butterfly valves (except buried valves) are wheel operated for ease of operation. Wheel actuators are installed in readily accessible positions. Chain wheel actuators are provided with hammer blow starting when located more than 6 feet above floor. Butterfly valves 6 inches in diameter and larger are equipped with enclosed gear actuators and handwheels.

As a special pumping station requirement, the Agency may consider electric actuators for isolation valves 16 inches in diameter and larger. AC reversing-type electric actuators are used for electrically operated isolation valves. Electrical actuators on buried piping are installed in valve vaults for ease of maintenance.

Actuators for pump control valves are described in paragraph 9.1.14 C of this chapter.

9.1.15 SITE WORK

A. Site Constraints:

The DESIGN CONSULTANT reviews the Predesign Report (if applicable) from the Agency for site constraints that may affect the design appearance, character, materials selection, earthwork, and location on the pumping station site. Views of the facility from areas surrounding the project site are analyzed, and alternatives discussed to harmonize the appearance of the facility with its visual context. Regardless of the visual circumstances, the pumping station operating floor is in all cases located above the 100-year flood elevation.

Pumping station sites may not be located on easements, but must be entirely located on Agency-owned land.

B. Construction Sequencing:

Where bypass pumping for an existing pumping station is required, the DESIGN CONSULTANT provides a sequence of construction on the drawings and in the special provisions of the specification, describing the required construction sequence for performing the bypass operation.

C. Site Utilities:

The DESIGN CONSULTANT identifies and coordinates with appropriate local utility agencies representatives. The DESIGN CONSULTANT also refers to the Predesign Report (if applicable) for any available information on utilities that might be impacted by each project.

The DESIGN CONSULTANT designs the water service with a reduced pressure backflow protection device installed after the water meter, in accordance with the Water Agencies' Standard. The site water piping system should include a 1-inch water service and hose bibb placed inside the pumping station building for cleaning the building and adjacent site. The design includes parking posts placed around the reduced pressure backflow prevention device to protect it from damage due to traffic.

D. Access and Parking:

A vehicle access road at the pumping station site allows the positioning of a crane truck of the size required for removal of the largest pumping station equipment through roof hatches when appropriate.

The site also includes sufficient parking space for two 3-ton maintenance trucks.

Avoid locating truck or crane truck access road and parking over inlet discharge piping penetrations into the pumping station walls to avoid pipe shear loadings at these locations.

All vehicle access roads to pumping stations are asphalt paved and a minimum of 24 feet wide. All access roads must be designed with accurate vehicle turning radius and provisions for vehicle turn around.

E. Security:

The pumping station site is normally completely enclosed by an 8-foot high fence. The fence is chain-link or architectural wrought iron type to meet community architecture requirements. The fence has webbing to reduce station visibility if required by a community architecture review. An 8-foot high masonry brick wall around the station may also be constructed where appropriate to match existing architecture. All pumping station outside isolation valves, valve vaults, domestic water fixtures, irrigation system fixtures are located inside the site security fencing. If possible, the security fence is located on or immediately adjacent to the property line.

As a special pumping station requirement, the DESIGN CONSULTANT may be required to design a video camera-based security system with strategically located cameras and an intrusion alarm system.

F. Site Lighting:

The pumping station site lighting is controlled by a photocell equipped with manual on/off control. For outdoor lighting, the DESIGN CONSULTANT selects luminaries that produce the least glare over the surrounding area.

Exterior fixtures are vandal-resistant.

G. Landscaping:

All pumping stations are landscaped in a manner that meets community standards and conforms to the Agency's requirements. The landscape design must be perceived as an extension of the concepts established for the materials and form of the building selected to blend with adjacent areas. Landscape designs must be developed by a licensed landscape architect.

The landscape development of pumping station sites is kept to the minimum and is low maintenance. Irrigation systems and plant material are installed outside the Agency's security fence unless it is absolutely necessary to screen objectionable views of the facility from the community or to prevent the erosion of manufactured slopes.

Landscaping selected by the DESIGN CONSULTANT should be drought tolerant. Landscaped features on the pumping station site should be low maintenance and low irrigation (xeriscaping) types.

Landscaped areas are provided with an automatic irrigation system. A reduced pressure backflow prevention assembly is placed in the irrigation piping system to protect the domestic water supply from pollution. A framed, laminated control schematic drawing of the installed irrigation system is mounted in the door of the controller cabinet inside the pumping station.

9.1.16 STATION SUPPORT SYSTEMS

A. Ventilation:

The DESIGN CONSULTANT designs ventilation to cool the facility using outside air as a cooling medium. The DESIGN CONSULTANT calculates the total sensible cooling load for the pump station building/structure, including both external loads (building/structure envelope) and internal loads (motors, occupancy, lighting, and miscellaneous heat generating equipment). The required ventilation rate must be based on ASHRAE HVAC Applications, Chapter Ventilation of the Industrial Environment, paragraph Ventilation Airflow for Temperature Control, latest edition. The calculation formula is:

$$Q = qs/1.08 \Delta t$$

Where:

Q = required ventilation rate, cfm
qs = total sensible heat to be removed, Btu/hr
 Δt = temperature rise of the air, °F

The DESIGN CONSULTANT must use ASHRAE Weather Data for Region X for the project location, summer 2% Dry Bulb Temperature column (°F as design outdoor air temperature, and $\Delta t = 10^\circ\text{F}$).

If no significant sensible cooling load is encountered, the DESIGN CONSULTANT uses 6 air charges per hour or 1.5 cfm/sf, whichever is greater, as a minimum with ASHRAE recommended Outdoor Air Requirements for Ventilation (ASHRAE Standard 62-1981).

The ventilation system must conform to the following codes standards and guidelines unless superseded by more stringent local codes:

- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
- Cal-OSHA General Industry Standards
- National Electric Code (NEC)
- National Fire Protection Association Standards (NFPA)
- Sheet Metal and Air Conditioning Contractors National Association (SMACNA) Standards
- Uniform Building Code (UBC)
- Uniform Fire Code (UFC)
- Uniform Mechanical Code (UMC)

Design the ventilation system for noise levels as described in design guide Section 9.3. This noise limit includes the sum of fan intake, fan discharge, motor, and casing rotation noise. The maximum fan noise load at 1 meter distance is 85 dBA. Ventilation systems must specify the use of low noise fans.

Provide replaceable dust filter elements on inlet wall louvers or supply air fans. Inlet ventilation dust filters are installed to minimize entry of dust into the station. Filters are located at access doors in the ducting, fan heads, and at convenient locations for maintenance access. Provide a label on the ducting at the filter access location to alert operating personnel to the need to check or replace filters at specified intervals or as measured by a differential pressure gauge. Inlet wall louvers are weatherproof and are equipped with a bird screen or insect screen, as applicable.

Inlet/discharge silencers may be required for noise attenuation. If an inlet/outlet blower system requires noise attenuation, a silencer is provided.

As a special pumping stations requirement, exhaust louvers have motor operated grates that open when the ventilation system is in operation.

Pumping station ventilation systems operate by thermostatic control with manual on/off override.

Underground pumping station areas in coastal and other high-humidity areas are equipped with a wall-mounted dehumidification system.

B. Overhead Hoist:

The DESIGN CONSULTANT designs an overhead hoist system for the installation, disassembly, maintenance, and removal of piping, motors, pumps, valves, flow meters, and other major components in the pumping station. Design of all hoists must be in accordance with the Hoists Manufacturers Institute.

On large pumping stations with three or more horizontal split case pumps having motors of 100 hp or greater, the DESIGN CONSULTANT designs a traveling bridge crane of the top running type consisting of electric drives, end truck, trolley hoist, and controls.

On smaller pumping stations with a horizontal pumping configuration, the DESIGN CONSULTANT designs a hoist system using monorails or jib crane systems with manual hoists.

On pumping stations using vertical turbine pumps, the DESIGN CONSULTANT provides roof access hatches or operable skylights for removal of pumps and motors using truck-mounted mobile cranes. A monorail or jib crane system with manual or electric hoists is provided for maintenance and repair over control valves and flow meters.

Install a high access door at the end of the crane rail to allow for positioning a truck-mounted crane inside the station for the removal of equipment.

On some pumping stations, embedded eyebolts may be provided to assist in equipment removal.

C. Water Supply and Toilet Facilities:

The potable water supply is protected by a reduced pressure principle backflow preventor in accordance with local code requirements. The DESIGN CONSULTANT requires the Construction Contractor to pay all installation costs for a 1-inch water service per Water Agencies' Standard (if applicable). The Construction Contractor may also be required to pay water billings (as required by the Agency) until final acceptance of the pumping station by the Agency.

As a special pumping station requirement, some stations may be designated for inclusion of toilet facilities. No station has toilet facilities that cannot be discharged to a municipal sewer system. All sanitary drains designed by DESIGN CONSULTANT must be in conformance with Water Agencies' Standard, Uniform Plumbing Code (UPC), and all local codes.

D. Instrument Air:

Instrument air systems, when required, are designed for a maximum system pressure of 60 psig. Compressors are nonlubricated, air- or liquid-cooled, sized for not less than 12 cfm per unit, but in any case, at least 20 times the anticipated maximum air demand. The maximum compressor noise level at one meter distance is 85 dBA. A redundant compressor is provided. ASME-approved receivers are sized to provide a run time of not less than 15 minutes. Compressed air is aftercooled and dried using a regenerating desiccant air dryer. Dryers are installed on the system side of receivers and are sized for not less than twice the anticipated air demand.

E. Pump Room Drainage System:

The drainage system consists of a floor drain, hub drain, cast iron drain pipe, holding sump and sump pumps. The drainage system is designed to handle drainage from the pump seals, power check valves, air release valves, and housekeeping. Floor drains are located and floor slopes designed so that equipment pads do not interfere with drainage. The drainage system is discharged to the municipal sewer system (include a P-trap and devices to keep P-trap full of water). The DESIGN CONSULTANT consults with the local governing authority to design the drainage system to meet all applicable codes, including cases where a municipal sewer is not available. If required, the holding sump is designed with adequate volume to prevent the pump from cycling in excess of the number of starts per hour recommended by the motor manufacturer. The sump is covered with aluminum grating.

Sump pumps are duplex-type submersible pumps complete with lifting chain, discharge valve, check valve, and piping, starter, level controls, and automatic alternator. High water level alarms are connected to the main pump station control panel.

F. Fire Extinguisher:

A fire extinguisher rated for Class A, B, and C type fires is installed in each pumping station. If an emergency generator is included in the pump station design, a similar fire extinguisher is also provided in the engine room in the outside generator enclosures.

9.1.17 INSTRUMENTATION AND CONTROLS

A. Pump Control Description:

The DESIGN CONSULTANT describes the pump control sequence description, including control valve operation, safety interlocks and control resets. These descriptions are titled "Control Strategies" and are sufficiently detailed to guide the Construction Contractor in programming the programmable logic controller (PLC). The DESIGN CONSULTANT refers to the Agency for specific requirements.

Two types of pump sequence control are covered: pressure control, normally used for pumps designed to maintain a pressure set point in a closed zone and level control, where the pump sequencing depends on level set points in reservoirs and standpipes. A third type of control may be required where the pump station serves a closed zone and a reservoir simultaneously. This type of control may combine the requirements of pressure and level control if the pressure and flow rates cannot be met by constant speed pumps alone.

B. Pressure Control of Pumps:

The DESIGN CONSULTANT determines the control philosophy based on the number of pumps, the flow capacity of each pump if different sizes are used, the pump curves, and the pipeline system head curve. To meet the closed zone pressure set point requirements at wide flowrate ranges, the pumps are driven by variable frequency drives (VFDs). The DESIGN CONSULTANT determines the rpm range for controlling each pump by examining the pump efficiency curves versus the flow curves. For instance, driving the pump past 90% flowrate capacity may cause a disproportional increase in electric power consumption.

Pressure surges caused by the transition from one-pump to two-pump operation, two to three, etc., must be avoided as described in the following control sequence.

C. VFD Pump Control Sequence:

The following pump control sequence assumes a four-pump closed pressure zone, three pumps active, one on standby, same size and driven by VFDs. The pump control sequence is performed by the PLC with programmed software logic and adjustable software timers. As the minimum pressure set point for pump operation is reached, the first pump starts up at minimum rpm. As the flowrate demand increases and the measured pump station discharge pressure decreases, the pump rpm increases to a programmed maximum. When an additional pump is required, the PLC starts up a second pump at minimum speed and keeps the running pump at maximum rpm. As the flow demand increases, the second pump rpm increases to its maximum and with increasing demand the third pump starts at minimum rpm while the first and second pumps continue to run at a maximum rpm. When the flow demand decreases, the pump sequence reverses order. The fourth pump remains on standby until the pump rotation places it in active duty.

The preceding example assumes a VFD for each pump and all pumps of the same size. This arrangement provides smooth transition when additional pumps are started or stopped. The DESIGN CONSULTANT may propose a control system that uses VFDs and constant speed pumps to reduce cost. However, this proposal must be supported by pump and system curves for the specific pump station and approved by the Agency.

The VFD for each pump is provided with an across the line bypass motor starter selected by a 2-position switch to be used in case of VFD failures or upset conditions.

D. Pumping Station Surge Control:

The DESIGN CONSULTANT provides the means to avoid surges on pump start/stop operation. The means to achieve surge control may consist of pump discharge control valves, hydropneumatic surge tanks, pressure relief valves, or a combination of them. Pump discharge control valves are covered in paragraph 9.1.14 C of this chapter. Control valves are provided with valve position limit switches (open/closed) so that the PLC verifies that the valve is closed before starting and stopping the corresponding pump. If hydropneumatic surge tanks are provided, they must have a complete control system and alarm outputs to the PLC. The alarms must include high or low water level, air compressor trouble, etc. The DESIGN CONSULTANT provides and the surge tank vendor verifies calculations defining tank capacity, water/air level ratios, and the connecting pipe size that determines the water flowrate in and out of the surge tank.

E. Level Control of Pumps:

Pump stations designed for reservoir level control are sequenced based on reservoir level set points. The pumps are normally of the same size with solid-state soft start motor starters and bypass contactors.

The reservoir level signal is transmitted to the pumping station by remote microwave radio or leased line telemetry.

F. Level Control Pump Sequence:

Pumping stations designed to feed reservoirs or tanks are provided with single-speed pump motors. The PLC control logic is designed to avoid excessive pump cycling. The start/stop cycles per hour are within the motor manufacturers specifications. The PLC program allows the operator to perform level set points and timer adjustments through the operator interface on the control panel. The timers are intended to delay the start/stop of pumps upon detection of reservoir level set points.

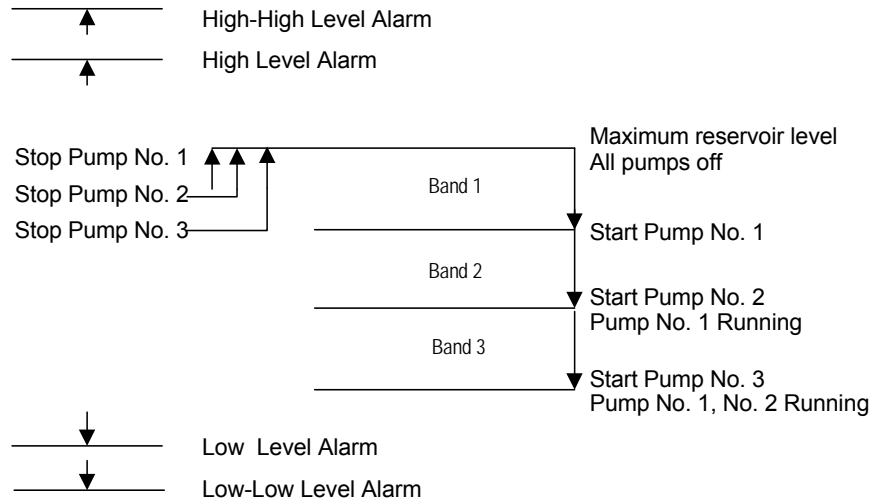
G. Typical Level Control Sequence:

Assume three constant speed pumps filling a reservoir. The PLC interlocks prevent simultaneous pump starts, which could happen after a power failure when two or more pumps are running. In that case, 15-second intervals are allowed between pump starts.

1. Sequence Control Description:

Figure 9.1-3 shows that the reservoir water level has been at the top of band 1 and drops to the bottom of band 1. After an adjustable delay start pump 1. If the level remains within band 1 and 2, continue pumping with pump 1. When the level rises to the top of band 1, stop pump 1. If the level drops below band 2 while pump 1 is on, start pump 2. When the level rises to the top of band 2, stop pump 2. This sequence repeats similarly for pump 3. Pumps are rotated periodically or at each cycle to allow equal wear. Pump rotation is displayed on the operator interface.

**Figure 9.1-3
Typical Pump Level Control Diagram**



H. Flow Measurement and Pressure Instrumentation:

In addition to the pump discharge header pressure transmitter, an in-line magnetic flowmeter is installed in new pump stations on the station suction or discharge piping to monitor pumping station throughput. A pressure transmitter and a pressure switch is also installed on the pump station suction header. In the event of low suction pressure, the PLC shuts down the pumps sequentially until the header suction rises to safe levels or until all pumps are turned off.

Flowmeter selection includes an evaluation of the facility criticality, including consideration of a shutdown necessary for meter maintenance. Magnetic flowmeters are preferred for new facilities; however, insertion flowmeters may be permitted by the Agency.

I. Control Panel Pump Selector Switches:

Three position selector switches for each pump are provided on the control panel. The positions are H-O-A. In the "H" (hand) position, the pump runs continuously without PLC control. This mode is for testing or emergency only. In the "O" (off) position, the pump is shut down and cannot be started. In the "A" position, the pump start/stop operation is controlled by the PLC based on the logic programmed by the Construction Contractor.

J. Control Panel Operator Interface:

To minimize the number of pushbuttons and switches and provide process graphics and alarm data to the operator, an operator interface is provided on the control panel. The graphics are configured by the Construction Contractor in coordination with the Agency's Telemetry, Power, and Control Group. The operator interface is Modicon Panelmate 3000 or equal.

K. Pump Station Telemetry:

Pump station data transmission to the AWTF Central Control System must be effected as directed by the Agency.

As a minimum, the telemetry data transmitted including:

- Pump running
- Motor high temperature
- Pump circuit breaker/motor starter failure
- Control power failure
- Main power phase unbalance/failure
- Pump control valve failure
- Low suction pressure
- Discharge flow rate and pressure
- Pump room flooding
- Intrusion alarm
- Generator run status and failure
- Ventilator fan failure, etc.
- Pumping station ambient temperature
- Communication failure

9.1.18 ELECTRICAL DESIGN AND EMERGENCY POWER GENERATOR

A. Electrical Design Work:

The DESIGN CONSULTANT conducts all electrical studies required for the BODR (e.g., relay coordination, short circuit, voltage drop and motor starting analysis). The DESIGN CONSULTANT also prepares the technical specification sections necessary to assemble a complete electrical package and develops the electrical drawings for pumping stations necessary to construct a complete electrical package.

At existing pumping stations where additional load is being added to the distribution system, the DESIGN CONSULTANT obtains the maximum electrical demand reading for the past two years from the electrical utility company, and uses this reading as the starting base load.

B. Codes and Standards:

The pumping station electrical system designed by the DESIGN CONSULTANT must comply with the requirements of the Agency, NEC, ANSI, UL, NEMA, and IEEE, as applicable.

C. Electrical Service and Distribution:

Distribution (utilization) voltages are 4.16 kV, 480 V, 208 V, and 120 V unless other voltages are specified for special cases. Incoming service voltages are coordinated with the utility company and the Agency.

The DESIGN CONSULTANT designs the pumping station power distribution system so that no single fault or loss of preferred power source results in disruption (extended or momentary) of electrical service to more than one motor control center (MCC) associated with vital components. To meet this requirement, the electrical power distribution system incorporates redundant power sources.

Vital components serving the same function are divided as equally as possible between at least two MCCs. Nonvital components are divided in a similar manner.

Incoming power metering can be remotely read via telephone modem.

Outdoor installations are nonwalk in weatherproof enclosures.

During pump startup, the voltage drop at the motor terminals may not exceed 15%. Feeder and branch circuit conductors are sized so that their combined voltage drop does not exceed 5% with a maximum of 3% in either feeder or branch circuit.

Utilization voltage ratings are as follows:

1. Motors: Smaller than 3/4 hp, 115 volts, single-phase, 60 Hz 3/4 hp and larger (up to 300 hp), 460 volts, 3-phase, 60 Hz
2. Miscellaneous nonmotor loads of 0.5 kW and less are single-phase rated at 115 volts, 60 Hz.
3. Nonmotor loads larger than 0.5 kW are rated at 460 volts, 3-phase, 60 Hz, unless this voltage rating is not available for the equipment selected.
4. Lighting: Outdoors = High pressure sodium type, 277 or 115 volts, single-phase.
Indoors = Fluorescent, 115 volts, single-phase.
5. General-purpose receptacles are rated 20 amps, 120 volts, single-phase.

6. Special purpose receptacles may be 120, 208, or 480 volts, 3-phase as required.
7. All ac control power circuits are 120 volts, single-phase.
8. Special purpose dc control circuits may be 125 volts, 48 volts, or 24 volts.
9. All instrumentation power supplies are 120 Vac single-phase, 60 Hz.

D. Electrical Equipment:

The DESIGN CONSULTANT sizes electrical equipment to continuously carry all electrical loads without overloading. Equipment and materials are rated to withstand and/or interrupt the available fault currents, with at least a 25% reserve margin for electrical load growth. Electrical power conductors are sized according to the heating characteristics of conductors under fault conditions. Electrical equipment panels are provided with cooling fans.

1. Medium Voltage Motor Controllers:

Medium voltage controllers are modular design, vacuum contactor type. Where required by the power supply, or if the voltage dip exceeds the required maximum value, reduced voltage motor starters are used. A reduced voltage motor starter may also be used as a surge protection device for the constant speed pump drives. The motors are started slowly to reduce surges in the pipeline.

Indoor enclosures must be NEMA 12 rated.

All MV starters are furnished with electronic protection modules with communication capability.

2. Variable Frequency Drives:

Variable frequency drives (VFDs), where required, are provided with the pump and motor to provide unit responsibility for a system that performs over the required head and flow ranges. The VFDs are used to drive induction motors, and are PWM type.

All VFDs have remote control capabilities via a MODBUS (+) communication interface port.

3. 600-Volt Motor Control Centers:

Low voltage motor control center (MCC) assemblies must conform to the UL and ANSI standards for NEMA Class 2, type B wiring.

All breaker handle mechanisms have padlocking devices on the off position.

All indicator lights mounted on the MCC are push-to-test type.

All combination magnetic starters have MCPs and time delay mechanisms to prevent the unit from dropping out during momentary utility voltage dips.

A full-length ground bus must be provided.

4. Switchgear:

Switchgear assemblies conform to UL and ANSI standards, and comply with the service requirements of the utility company.

For outdoor applications, the switchgear must be weatherproof NEMA 4, nonwalk-in type.

Busbars are copper, fully insulated and silver-plated at joints. A full-length ground bus must be provided.

E. Grounding:

All feeders have an equipment grounding conductor in the same raceway.

Equipment grounding conductors must be sized in accordance with NEC table 250-95.

F. Instrument Power:

All 120-volt power to instruments and instrument panels is derived from a dedicated instrument power panel from a shielded transformer, not from a general lighting and convenience receptacle panel. Provide separate fuses for each field device.

An uninterruptible power supply (UPS) is provided for all main control panels, RTUs, RIOs, PLCs, and all other process controllers as required for the specified instrumentation and controls.

G. Emergency Power:

1. Emergency Plug-in Connection:

In stations without an alternative backup power source (i.e., second service or a dedicated onsite emergency power plant), install a manual transfer switch and an emergency plug-in power connection to the pumping station for use with a portable generator.

The pumping station is also equipped with a manual transfer system that requires the use of an enable key to sequentially open the line power service and then transfer to the emergency power service connection.

The transfer switch has the same current amperage interrupt rating (AIC) as the line power main breaker.

The following warning sign is posted on the manual transfer switch panel:

DO NOT TRANSFER POWER UNDER LOAD

2. Emergency Power Generator:

Diesel engine generator units may be installed with special approval from the Agency. Need for an emergency power plant is established in the Predesign Report (if applicable) or the BODR.

The preferred fuel tank installation is a frame-mounted fuel tank under the emergency generator unit (surrounded by a spill containment dike) or an aboveground tank installed in an aboveground block-wall enclosure incorporating a confinement dike. An aboveground tank is used where possible. All diesel storage tanks have a desiccant dry-air breather on vents to prevent water condensation in the tank. The fuel tank contains sufficient fuel to sustain a minimum of 24 hours of continuous operation.

The DESIGN CONSULTANT requires that a 1-year standard service contract for the emergency generator be provided by the Construction Contractor.

The pumping station has an interlock-protected emergency power automatic transfer switch (ATS) to automatically start the generator in the event of loss of main power (i.e., phase of power, reverse power, or low voltage brownout). The ATS is mounted in sight of the generator control panel or remote status annunciator panel for ease of operation. The ATS is provided with communication provisions for remote annunciation and control via the local telemetry system.

H. Lighting:

Refer to paragraph 9.1.16 D of this chapter for lighting voltages. The State of California Energy Conservation Standards applies where applicable.

Lighting levels are as follows:

Area	Illumination Level
Electrical Equipment Rooms	40 footcandles
Exterior Lighting	0.1-1 footcandle
Pumping Area (dry well)	30 footcandles
Mechanical Equipment Rooms	30 footcandles
Restrooms	30 footcandles

Lighting in pumping stations is switched. The pathway to the main lighting switch is lighted with nonswitched lighting fixtures.

Exterior lighting around unattended pumping stations, is provided with key-operated switching located at the property entrance gate.

Emergency egress lighting in all interior areas of the pumping station is accomplished with units with emergency battery backup packs illuminating the egress path to the outdoors. 90-minute battery backup capacity is provided.

I. Receptacles:

20 amp, NEMA 20-R, 120-volt grounding convenience receptacles for GFI plugs are provided throughout the pumping station facility so that all working areas, can be reached by a 25-foot-long portable cable (extension cord).

One 200-amp, 480-volt, 3-wire, 4-pole twist lock receptacle is provided so that the receptacle can be reached by a 50 foot long cord.

All receptacles in outdoors are in weatherproof enclosures for GFI plugs.

J. Electrical Equipment Room:

The electrical equipment room is separate from the pump room. It is either located in a separate building or be separated from the pump room by a divider wall fitted with a fixed viewing window.

9.1.19 ARCHITECTURAL TREATMENT

This section provides a general basis for the approach to architectural design of pumping stations. The following guidelines and criteria are provided to ensure a consistent and thorough design process for each facility. Although the guidelines described in this section apply to pumping stations, the general concepts could be applied to other Agency facilities which incorporate pumping stations and other related buildings/structures (e.g., combined reservoir, pumping station facilities).

A. Design Performance Guidelines:

The DESIGN CONSULTANT meets with Agency's staff to establish appearance and physical performance criteria for the facility. Areas of focus include the sizes and configurations of the major functional elements to be housed in the facility, and the deployment and interrelationships of supporting mechanical, electrical, and maintenance provisions. Topics also include:

1. Discover, document, and prioritize functional goals for the facility, including spatial needs and hierarchy of importance, public image, the degree or level of security appropriate to the facility location, functions to be housed, the scope of future expansion and flexibility expected, desired links to other functions on the project site, maintenance guidelines, and HVAC, electrical, lighting, and acoustical criteria. The use of the new facility is discussed and documented in terms of intended conformance with, or departure from, existing employee health and safety policies.
2. Discover and document the degree and type of human interaction anticipated to occur within and around the planned facility, including Agency personnel and public access to the facility in the form of visits by non-Agency personnel. These considerations have key relevance in the design of the facility within the context of regulations governing handicap access. The building design resulting from these conversations is affected in areas such as the number and location of emergency exits, fire detection and suppression system, the design of zones of safety, horizontal and vertical clearances, and other personal safety, acoustic and lighting safety provisions.
3. Determine locations and sizes of structures and other functional systems which may already exist at the project site, as well as the availability and types of utility services which may be required. Develop strategies to successfully integrate the design of the new facility into this context.
4. Review the impact of the project on existing drainage patterns. Develop mitigation strategies if necessary.
5. Investigate existing zoning constraints, applicable building codes, and anticipated public and governmental review procedures necessary during the course of the design. Develop strategies and assign responsibilities for their successful negotiation
6. Review and document existing and future planned land uses around the facility site. Determine guidelines for the design and character of the new facility so that it harmonizes as effectively as possible with its visual and social context.
7. Review and incorporate mitigation measures included in environmental documents for the project.
8. Review and incorporate public input, if applicable.
9. The DESIGN CONSULTANT utilizes the minimum criteria for noise control described in design guide Section 9.3. Additional or stricter criteria may be established in the environmental approval process. The DESIGN CONSULTANT shall utilize the most conservative criteria established.

B. Design Appearance Guidelines:

As an extension of the discussions in the preceding paragraphs, the DESIGN CONSULTANT and the Agency establish criteria for the appearance and physical performance of the structural system and building envelope. The architectural design should be developed in character, style, form, color, and materials to harmonize effectively with its surrounding environment. Suggested design parameters to assist in these aspects of the design of the facility include:

1. **Height of Structures.** The facilities are kept as low in profile as is functionally possible. Where appropriate, the design should de-emphasize verticality and encourage the grounding of planar elements of the facility into the natural landscape. Low, horizontal site walls, berming, and the use of sloping wall planes are to be considered in achieving this balance.
2. **Reflective Finishes.** Visible and highly reflective materials and surface finishes should be avoided on the exterior of the facility.
3. **Exterior Walls.** The use of low maintenance indigenous materials such as masonry and concrete for the exterior walls of the facility is encouraged. The use of surface textures and horizontal banding of harmonious colors are some of the techniques to be considered in blending the facility with its environment. Material coloration should be achieved through the use of integral coloration and, in the case of concrete, pigmented admixtures, rather than applied coloration such as paint, which must be maintained.
4. **Roofs.** Just as with the massing and materials of the exterior walls, the design of roof systems should be carefully developed to harmonize with the visual context of the facility. Where flat roofs are appropriate, they should be predominately hidden by parapet walls. Where pitched roofs are desired, consideration should be given to selecting pitch, materials, and coloration to harmonize with surroundings. Highly reflective roof surfaces must not be visible from adjacent property. Mansard and jogging roof lines should be employed only when appropriate to the setting. The use of securable skylights for natural lighting is encouraged where feasible. Also provide securable skylights or access hatch for ease of equipment removal using a mobile crane.
5. **Windows.** Where windows are appropriate to the design, they should be selected carefully for energy efficiency, acoustic characteristics, and security. Glazing systems are designed to avoid light leakage to adjacent property as direct glare or reflected glare from sunlight. Glass tinting and window frame colors should be chosen for their consistency with the palette of materials and colors selected for the facility.
6. **Insets, Grills, Trim and Accents.** Insets, grills, trim material, and accents should be employed judiciously and only where necessary or appropriate for compatibility with adjacent structures. Insets, grills, trim, and accents are consistent with the color palette chosen for the facility and should avoid bold, strong, or reflective colors.
7. **Doors and Frames.** Door and frame colors are compatible with the wall surface in which they are located.
8. **Lighting.** Lighting should satisfy functional and security needs while not creating light pollution in the form of point sources of direct glare visible from a distance. Lighting should be sensitive to the privacy of adjacent land uses. Fixtures should be carefully selected for efficiency, cut-off, consistent lamp coloration throughout the project, and effectiveness in delivering only the light necessary to the task, while avoiding unnecessary spill lighting beyond site boundaries. Low-level light fixtures, which light immediate areas, are

encouraged. Natural lighting of the interior of the building in the form of skylights and clerestory windows is also encouraged.

9. **Equipment and Service Areas.** All mechanical and electrical equipment are screened from public view.
10. **Materials - Safety.** Materials used in the construction of the facility conform in composition and application to all applicable regulations, including those concerning volatile organic content, lead, mercury, CFCs, and asbestos.

The Pre-design Report contains discussion of site constraints that may affect the design appearance, character, materials, selection, massing and location on the project site (if applicable). Traditionally established Agency preferences and guidelines for material and appearance systems, structural systems, and major building envelope systems are discussed and their appropriateness to the specific application assessed. These preferences and guidelines are developed in the context of the specific location of the project site; therefore, not all facility design should be expected to have the same architectural theme and character. Construction materials and methods are established and defined, in terms of their physical appearance and overall visual effect in harmonizing with the surrounding environment, their emergency from the basic structural system, and their appropriateness in accommodating the deployment of mechanical and electrical systems within the facility.

Weathering systems are also defined in terms of the area's desert climate. The roofing system and the building perimeter envelope are established for optimum durability over the full range of climatic variations typical to the region.

These examinations form the basis of directions to the DESIGN CONSULTANT about the appearance of the new building. From these discussions, the DESIGN CONSULTANT develops specific graphic and written statements defining the architectural theme and character of the new structure, as well as its relationship to other functions on the project site and its harmony with the visual context of surrounding land uses. Provide a rendering if required by the Agency.

C. Site Constraints:

Finally, the DESIGN CONSULTANT reviews the Agency's requirements for a discussion of site constraints that may affect the design appearance, character, materials selection, massing, and location on the project site. Views of the facility from areas surrounding the project site are analyzed and alternatives discussed to harmonize the appearance of the facility with its visual context. The DESIGN CONSULTANT ensures that view sheds are optimized while hydraulic elevations and storm drainage provisions are preserved. Regardless of the visual circumstances, the facility in all cases is located above the 100-year flood elevation.

D. Space and Function Requirement Program:

The DESIGN CONSULTANT documents the topics of discussion and directions established in the facility criteria meeting(s) in a space and function requirements program. This document may be in any form, from a simple memorandum to a bound report, depending on the size and complexity of the project. More significant than its form, the report must thoroughly document the understandings reached in the meeting(s). The document contains a summary establishing gross area and volume requirements, as well as a schematic of the basic functional relationships within the facility. It also completely describes the parameters of appearance, function, size, and layout. As such, the space and function requirements program is a distillation of all the information necessary to allow a competent design to be developed. The Pre-design Report serves as the point of beginning for this program.

E. Program Review and Approval:

The DESIGN CONSULTANT submits the space and function requirements program to the Agency, who reviews the material thoroughly and comments on any additional items or corrections that may be required. If the program information is found to be a clear, concise and accurate statement of requirements, the Agency approves the report.

F. Building Design:

After Agency approval, the DESIGN CONSULTANT proceeds with design of the facility. Requirements for basic functional relationships and area and volume requirements are developed and refined into plan, elevation, and section views of two separate design schemes. While schematics, the drawings are accurate to scale and incorporate all major program requirements. The DESIGN CONSULTANT meets with the Agency to present both schemes. Each alternative is described in terms of how well it embodies program requirements. Structural systems, building envelope, and major building systems are shown in both schemes. As a part of the DESIGN CONSULTANT'S presentation and description of the schemes, the relative merits, advantages, and potential criticisms of each scheme are discussed. The meeting culminates in a decision by the Agency of the selected scheme and any necessary adjustments. Clear directions are given to the DESIGN CONSULTANT on the final course of development to be pursued.

G. Construction Documents:

After the Agency's decision, the DESIGN CONSULTANT proceeds to develop the selected scheme into Contract Documents.

9.1.20 CORROSION CONTROL

The DESIGN CONSULTANT provides appropriate and detailed information in the Contract Documents describing the following requirements (see also design Section 11.1):

A. Protective Coatings and Linings:

The term "coatings" refers to materials applied to the external surfaces of various structures (buried, submerged or exposed) for protection against corrosion. The term "linings" describes materials applied to the internal surfaces of pipes, tanks and equipment for corrosion prevention.

The DESIGN CONSULTANT selects appropriate coatings and linings, taking into account the service environment, ability of the coatings and linings to resist aging and maintain adhesion to the structure's surface, ability to be applied with minimal defects, ability to withstand normal handling and storage, reparability, cost, and availability.

Usually underground piping at pumping stations is not cathodically protected due to difficulties in electrical separation of the piping from other structures, which normally do not have cathodic protection (electrical grounding systems, underground ducts, conduit, reinforced concrete structures, etc.). At structures where adjacent transmission/distribution pipe is cathodically protected, the pump station must be made electrically discontinuous from the adjacent piping with the use of flange or coupling insulation kits. The coatings for buried piping at structures shall be in accordance with Water Agencies' Standard. Concrete embedded or cement-mortar coated pipes should be equipped with test stations and corrosion coupons for monitoring corrosion conditions of the pipes. The application of loose polyethylene wrappings for ductile iron pipes is not recommended.

Steel surfaces immersed in water (surge tank internals, for example) have appropriate linings or coatings which, in addition to general requirements are resistant to cathodic disbondment, since these surfaces require cathodic protection.

Coatings for steel surfaces exposed to atmosphere are aliphatic acrylic polyurethane coated.

More detailed information on coating and linings, including generic types of coatings and linings, their application and relevant standards is found in the Water Agencies' Standard.

B. Materials Considerations:

A vast variety of metallic and nonmetallic materials are normally used at pumping stations. Carbon steel, ductile iron, PVC, FRP, and concrete are in underground structures. Stainless steel is often used in contact with water as parts of valves, pumps, sluice gates, etc. Bronze is used for valve stems, pump impellers and shafts.

The DESIGN CONSULTANT thoroughly investigates the corrosion potential of soil, water, and atmospheric conditions at the pumping station site before selecting materials of construction for piping, tanks and equipment.

Recommendations on materials selection for soil, water, and atmospheric exposures can be found in the Water Agencies' Standard.

C. Cathodic Protection:

Normally, cathodic protection at pumping stations is applied to surge tank internals (impressed current type); some items immersed in water, such as sluice gates, valves, etc. (galvanic anode type); and for suction and discharge piping.

Detailed requirements for the successful application of cathodic protection under various environmental conditions, the evaluation of cathodic protection needs and testing procedures are described in the Water Agencies' Standard.

9.1.21 PUMPING STATION OPERATIONAL TESTING FACILITY ACCEPTANCE

The DESIGN CONSULTANT provides appropriate information in the Contract Documents to describe the following requirements:

A. Operational Test Procedures:

The DESIGN CONSULTANT prepares a schedule of operational tests to be witnessed by the Agency's staff that demonstrates the proper operation of all equipment at the station. The Construction Contractor is required to demonstrate the operation of all pump station mechanical equipment, electrical controls, emergency power operations and warning displays. Simulated failure conditions are initiated by the Construction Contractor as required to demonstrate warning displays.

B. Contractor Testing and Equipment Certifications:

The DESIGN CONSULTANT prepares specifications that require the Construction Contractor to test and adjust all equipment to ensure proper operation after all construction is completed. The specifications require that the Construction Contractor obtain the following motor and pump test data and equipment installation certification and provide it to the Agency during operational testing.

1. Installed Equipment Certification:

The DESIGN CONSULTANT prepares specifications that require the Construction Contractor to submit to the Agency, within 14 calendar days of installation, a letter from each major equipment supplier certifying that the equipment installed at the pumping station was installed and tested to manufacturer's recommendations.

The certifications from the Construction Contractor (and/or its equipment suppliers and subcontractors) certifies that major equipment was installed, tested and is operating to manufacturer's recommendations. Certifications are provided for the following major equipment in the station: pumps and motors, power check valves, emergency generator units, automatic transfer switches, diesel fuel tanks and day tanks, motor control centers, pump control panels, telemetry panels, flow meters, and pressure switches/transducers.

2. Factory Testing Report Pump Motors:

The DESIGN CONSULTANT prepares a specification requiring the Construction Contractor to have the pump motor manufacturer/supplier submit certified factory test information for the supplied units: motor heat run and efficiency test curves.

3. Factory Testing Report - Pump Unit(s):

Certified pump test curves recording the actual performance of installed equipment are prepared for each pump at the Construction Contractor's expense (in accordance with Hydraulic Institute Society test requirements). The test information also includes the following: TDH/GPM, motor current draw, motor RPM, and overall efficiency.

4. Vibration Analysis Report:

The Construction Contractor is required to provide a vibration analysis test report for the installed pumping and emergency generation equipment. This analysis and report is prepared by a state of California Registered Professional Mechanical Engineer experienced in this type of work.

9.1.22 Structural Guidelines

See design guide Section 9.2 Structural Guidelines.

9.1.23 Noise Control

See design guide Section 9.3 Noise Control Guidelines.

9.1.24 REFERENCE

- A. Should the reader have any suggestions or questions concerning the material in this section, contact one of the member agencies listed.
- B. The publications listed below form a part of this section to the extent referenced and are referred to in the text by the basic designation only. Reference shall be made to the latest edition of said publications unless otherwise called for. The following list of publications, as directly referenced within the body of this document, has been provided for the users convenience. It is the responsibility of the user of these

documents to make reference to and/or utilize industry standards not otherwise directly referenced within this document.

1. Water Agencies' Standards (WAS):

a. Design Guidelines:

1. Section 5.5, Air Valves
2. Section 9.2, Structural Guidelines
3. Section 9.3, Noise Control Guidelines
4. Section 11.1, Pipeline Corrosion Control Systems

END OF SECTION