# CITY OF THORNTON, COLORADO

## PROJECT NO. 12-777J1

## SOURCE WATER PUMP STATION

## TECHNICAL SPECIFICATIONS

## PROCUREMENT PACKAGE 1

## ISSUED FOR BID

## VOLUME 1 OF 1

## DIVISIONS 01-46

## NOVEMBER 2025

COLORADO LICENSED
BART LEE GILES
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**CITY OF THORNTON, COLORADO**

**THORNTON WATER PROJECT (12-777J1)**

**SOURCE WATER PUMP STATION - PROCUREMENT PACKAGE 1**

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# SECTION 01_11_00

# SUMMARY OF WORK

## PART 1 GENERAL

### 1.01 SUMMARY

A. Vendor, Manufacturer, and Supplier are used interchangeably within the specifications.

### 1.02 THE WORK

The Vendor shall complete all Work as specified or indicated in the Contract Documents. The Work is generally described as follows:

A. It is the Owner's intent to assign this procurement agreement to an installing contractor at a later time.

B. Furnish pumps, motors, variable frequency drives, and associated equipment and appurtenances for PMP-302, VFD-302, PMP-303, VFD-303, PMP-305, VFD-305, PMP-306, and VFD-306 as described in the Contract Documents. This includes shop drawings, shipment, delivery, and other requirements that will be coordinated to the satisfaction of the Owner and Engineer.

C. The following services are required: Shop drawings shall be provided to the Owner and Engineer. Warranty, manufacturer's field services (including installation check, commissioning assistance, training, certification of acceptable installation and operation) to final completion will be coordinated with the installing contractor to the satisfaction of the Owner and Engineer.

D. All equipment and materials provided under these Contract Documents shall be shipped and delivered at the expense of the Vendor, and all costs relative thereto shall be included in the Contract Price. No shipment shall occur prior to source testing (factory acceptance testing).

E. Shipment shall be coordinated with the Contractor and shall be shipped and delivered to Source Water Pump Station site in between Rocky Ridge Lake Reservoir No.1 and Water Supply Storage Reservoir No. 3 at approximate latitude and longitude of 40.669260, -105.087194. Shipment on roads within Larimer County will be required to use specific haul routes that will be designated by the installing contractor and approved by Larimer County at a later time.

F. Heavy equipment traffic will be subject to all weight limit restrictions along adjacent roadways and the Vendor will obtain oversize/overweight permits for delivery of equipment.

G. Installation of the equipment will be at a later time by the owner selected installing contractor. Vendor is required to coordinate with the installing contractor.

## PART 2 PRODUCTS (NOT USED)

## PART 3 EXECUTION (NOT USED)

END OF SECTION

# SECTION 01_31_19

# PROJECT MEETINGS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Meetings that the Vendor is required to participate in for each piece of equipment that is being submitted on, installed, or commissioned.

### 1.02 QUALIFICATIONS OF MEETING PARTICIPANTS

A. Representatives of entities participating in meetings shall be qualified and authorized to act on behalf of entity each represents.

### 1.03 BASIC MEETING REQUIREMENTS

A. Location:
   1. A video and telephone call-in option will be provided for meetings.

B. Notification:
   1. Meeting leader shall notify attendees of the meeting, including an agenda, prior to the meeting.

### 1.04 WEEKLY SUBMITTAL STATUS MEETINGS

A. Engineer or Construction Manager leads the meeting.

B. Vendor shall attend up to 6 weekly meetings to coordinate submittal requirements and status for equipment.

C. Location:
   1. Video call.

### 1.05 PRE-INSTALLATION MEETINGS (WILL OCCUR AFTER INSTALLING CONTRACTOR IS ON PROJECT)

A. Installing contractor leads the meeting.

B. Vendor shall attend meeting for pre-installation of each piece of their equipment.

C. Location:
   1. Vendor may attend in-person or by video call.

## 1.06 COMMISSIONING COORDINATION MEETINGS (WILL OCCUR AFTER INSTALLING CONTRACTOR IS ON PROJECT)

A. Installing contractor leads the meeting.

B. Vendor shall attend meeting for commissioning of each piece of their equipment.

C. Location:
   1. Vendor may attend in-person or by video call.

## PART 2 PRODUCTS (NOT USED)

## PART 3 EXECUTION (NOT USED)

END OF SECTION

# SECTION 01_33_00

# SUBMITTAL PROCEDURES

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Requirements and procedures for Submittals to confirm compliance with the Contract Documents.

### 1.02 GENERAL INSTRUCTIONS

A. Vendor is responsible to determine and verify field measurements, field construction criteria, materials, dimensions, catalog numbers and similar data, and check and coordinate each item with other applicable approved Shop Drawings and Contract Document requirements.

B. Provide Submittals:
   1. That are specified or reasonably required for construction, operation, and maintenance of the Work.
   2. That demonstrate compliance with the Contract Documents.

C. Where multiple Submittals are required, provide a separate Submittal for each Specification section.
   1. In order to expedite construction, the Vendor may make more than one Submittal per Specification section, but a single Submittal may not cover more than one Specification section:
      a. The only exception to this requirement is when one Specification section covers the requirements for a component of equipment specified in another section.
      b. For example, circuit breakers are a component of switchgear. The switchgear Submittal must also contain data for the associated circuit breakers, even though they are covered in a different Specification section.

D. Prepare Submittals in the English language. Do not include information in other languages.

E. Present measurements in customary American units (feet, inches, pounds, etc.).

F. Must be clear and legible, and of sufficient size for presentation of information.

G. Page size, other than drawings:
   1. Minimum: 8-1/2 inches by 11 inches.
   2. Maximum: 11 inches by 17 inches.

H. Drawing sheet size:
   1. Maximum: 22 inches by 34 inches.
      a. Minimum plan scale: 1/8 inch equals 1 foot-0 inches.
      b. Minimum font size: 1/8-inch.
   2. 11-inch by 17-inch sheet:
      a. Minimum plan scale: 1/8 inch equals 1 foot-0 inches.
      b. Minimum font size: 1/8-inch.

I. Show dimensions, construction details, wiring diagrams, controls, manufacturers, catalog numbers, and all other pertinent details.

J. Provide Submittal information from only one manufacturer for a specified product. Submittals with multiple manufacturers for one product will be rejected without review.

## 1.03 SUBMITTAL ORGANIZATION

A. Organize Submittals in exactly the same order as the items are referenced, listed, and/or organized in the Specification section.

B. For Submittals that cover multiple devices used in different areas under the same Specification section, the Submittal for the individual devices must list the area where the device is used.

C. Bookmarks:
   1. Bookmarks shall match the table of contents.
   2. Bookmark each section (tab) and heading.
   3. Drawings: Bookmark at a minimum, each discipline, area designation, or appropriate division.
   4. At file opening, display all levels of bookmarks as expanded.

D. Where applicable (i.e., except for Drawings, figures, etc.), Submittal content shall be electronically searchable utilizing the PDF file as submitted.

E. Thumbnails optimized for fast web viewing.

F. Sequentially number pages within the tabbed sections:
   1. Submittals that are not fully indexed and tabbed with sequentially numbered pages, or are otherwise unacceptable, will be returned without review.

G. Attachments:
   1. Include with each Submittal a copy of the relevant Specification section.
      a. Indicate in the left margin, next to each pertinent paragraph, either compliance with a check (√) or deviation with a consecutive number (1, 2, 3).
      b. Provide a list of all numbered deviations with a clear explanation and reason for the deviation.
   2. Include with each Submittal a copy of the relevant Drawing, including relevant addendum updates.
      a. Indicate either compliance with a check (√) or deviation with a consecutive number (1, 2, 3).

b. Provide a list of all numbered deviations with a clear explanation and reason for the deviation.
c. Provide field dimensions and relationship to adjacent or critical features of the Work or materials.

H. Vendor: Prepare Submittal information in sufficient detail to show compliance with specified requirements.
1. Determine and verify quantities, field dimensions, product dimensions, specified design and performance criteria, materials, catalog numbers, and similar data.
2. Coordinate Submittal with other Submittals and with the requirements of the Contract Documents.
3. Check, verify, and revise Submittals as necessary to bring them into conformance with the Contract Documents and actual field conditions.

I. Vendor: Prepare “Or Equal” Submittal information.
1. Provide standard Submittal requirements.
a. In addition, provide in sufficient detail to show reason for variance from specified product and impacts.
2. Provide reason the specified product is not being provided.
3. Explain the benefits to the Owner for accepting the “Or Equal”.
4. Itemized comparison of the proposed “Or Equal” with product specified, including a list of significant variations:
a. Design features.
b. Design dimensions.
c. Installation requirements.
d. Operations and maintenance requirements.
e. Availability of maintenance services and sources of replacement materials.
5. Reference projects where the product has been successfully used:
a. Name and address of project.
b. Year of installation.
c. Year placed in operation.
d. Name of product installed.
e. Point of contact: Name and phone number.
6. Define impacts:
a. Impacts to other contracts.
b. Impacts to other work or products.
7. Vendor and represents the following:
a. Vendor bears the burden of proof of the equivalency of the proposed “Or Equal”.
b. Proposed “Or Equal” is equal or superior to the specified product.
c. Vendor will provide the warranties or bonds that would be provided on the specified product on the proposed “Or Equal”, unless the Owner requires a Special Warranty.
d. Vendor will coordinate installation of accepted “Or Equal” into the Work and will be responsible for the costs to make changes as required to the Work.
e. Vendor waives rights to claim additional costs caused by proposed “Or Equal” which may subsequently become apparent.

J. Vendor: Prepare substitution Submittal information.
    1. Provide standard Submittal requirements.
        a. In addition, provide in sufficient detail to show reason for variance from specified product and impacts.
    2. Provide reason the specified product is not being provided.
    3. Explain the benefits to the Owner for accepting the substitution.
    4. Itemized comparison of the proposed substitution with product specified, including a list of significant variations:
        a. Design features.
        b. Design dimensions.
        c. Installation requirements.
        d. Operations and maintenance requirements.
        e. Availability of maintenance services and sources of replacement materials.
    5. Reference projects where the product has been successfully used:
        a. Name and address of project.
        b. Year of installation.
        c. Year placed in operation.
        d. Name of product installed.
        e. Point of contact: Name and phone number.
    6. Define impacts:
        a. Impacts to Contract Price.
            1) Required license fees or royalties.
            2) Do not include costs under separate contracts.
            3) Do not include Engineer’s costs for redesign or revision of the Contract Documents.
        b. Impacts to Contract Time.
        c. Impacts to Contract Scope.
        d. Impacts to other contracts.
        e. Impacts to other work or products.
    7. Vendor represents the following:
        a. Vendor shall pay associated costs for the Engineer to evaluate the substitution.
        b. Vendor bears the burden of proof of the equivalency of the proposed substitution.
        c. Proposed substitution does not change the design intent and will have equal performance to the specified product.
        d. Proposed substitution is equal or superior to the specified product.
        e. Vendor will provide the warranties or bonds that would be provided on the specified product on the proposed substitution, unless the Owner requires a Special Warranty.
        f. Vendor will coordinate installation of accepted substitution into the Work and will be responsible for the costs to make changes as required to the Work.
        g. Vendor waives rights to claim additional costs caused by proposed substitution which may subsequently become apparent.

## 1.04 SUBMITTAL IDENTIFICATION NUMBERING

A. Number each Submittal using the format defined in the table below:

| | Spec Section Number | Dash | Initial Submittal - Sequential Number | Decimal Point | Subsequent Submittal Revisions Sequential Number |
|---|---|---|---|---|---|
| *Example 1 Description* | *Cast-In-Place Concrete* | | *8th initial Submittal* | | |
| | 03_30_00 | - | 0008 | | |
| *Example 2 Description* | *Cast-In-Place Concrete* | | *8th initial Submittal* | | *First revision to the 8th initial Submittal* |
| | 03_30_00 | - | 0008 | . | 1 |

## 1.05 SUBMITTALS IN ELECTRONIC MEDIA FORMAT

A. General: Provide all information in PC-compatible format using Windows® operating system as utilized by the Owner and Engineer.

B. Text: Provide text documents and manufacturer's literature in Portable Document Format (PDF).

C. Graphics: Provide graphic Submittals (Drawings, diagrams, figures, etc.) utilizing Portable Document Format (PDF).

## 1.06 SUBMITTAL PROCEDURE

A. Engineer: Review Submittal and provide response:
   1. Review description:
      a. Engineer will be entitled to rely upon the accuracy or completeness of designs, calculations, or certifications made by licensed professionals accompanying a particular Submittal, whether or not a stamp or seal is required by the Contract Documents or Laws and Regulations.
      b. Engineer's review of Submittals shall not release the Vendor from the Vendor's responsibility for performance of requirements of the Contract Documents. Neither shall the Engineer's review release the Vendor from fulfilling purpose of installation nor from the Vendor's liability to replace defective Work.
      c. Engineer's review of Shop Drawings, samples, or test procedures will be only for conformance with design concepts and for compliance with information given in the Contract Documents.
      d. Engineer's review does not extend to:
         1) Accuracy of dimensions, quantities, or performance of equipment and systems designed by the Vendor.

2) Vendor's means, methods, techniques, sequences, or procedures, except when specified, indicated on the Drawings, or required by the Contract Documents.
3) Safety precautions or programs related to safety which shall remain the sole responsibility of the Vendor.

e. Engineer can Approve or Not Approve any exception at their sole discretion.

2. Review timeframe:
   a. Except as may be provided in technical Specifications, a Submittal will be returned within 15 days.
   b. When a Submittal cannot be returned within the specified period, Engineer will, within a reasonable time after receipt of the Submittal, give notice of the date by which that Submittal will be returned.
   c. Engineer's acceptance of progress schedule containing Submittal review times less than those specified or agreed to in writing by the Engineer will not constitute Engineer's acceptance of review times.
   d. Critical Submittals:
      1) Vendor will notify Engineer in writing that timely review of a Submittal is critical to the progress of Work.
3. Schedule delays:
   a. No adjustment of Contract Times or Contract Price will be allowed due to Engineer's review of Submittals unless all of the following criteria are met:
      1) Engineer has failed to review and return first submission within the agreed upon time frame.
      2) Vendor demonstrates that delay in progress of Work is directly attributable to the Engineer's failure to return Submittal within time indicated and accepted by the Engineer.
4. Review response will be returned to the Vendor with one of the following dispositions:
   a. Approved:
      1) No Exceptions:
         a) There are no notations or comments on the Submittal and the Vendor may release the equipment for production.
         b) This response does not require more action.
      2) Make Corrections Noted - See Comments:
         a) Vendor may proceed with the Work, however, all notations and comments must be incorporated into the final product.
         b) Resubmittal not required.
      3) Make Corrections Noted - Confirm:
         a) Vendor may proceed with the Work, however, all notations and comments must be incorporated into the final product.
         b) Submit confirmation specifically addressing each notation or comment to the Engineer within 15 calendar days of the date of the Engineer's transmittal requiring the confirmation.
   b. Not Approved:
      1) Correct and Resubmit:
         a) Vendor may not proceed with the Work described in the Submittal.

b) Vendor assumes responsibility for proceeding without approval.
c) Resubmittal of complete Submittal package is required within 15 calendar days of the date of the Engineer's Submittal review response.

2) Rejected - See Remarks:
a) Vendor may not proceed with the Work described in the Submittal.
b) Submittal does not meet the intent of the Contract Documents. Resubmittal of complete Submittal package is required with materials, equipment, methods, etc., that meet the requirements of the Contract Documents.

c. Receipt Acknowledged:
1) Filed for Record:
a) This is used in acknowledging receipt of informational Submittals that address means and methods of construction such as schedules and work plans, conformance test reports, health and safety plans, etc.
b) This response does not require any more action.

2) With Comments - Resubmit:
a) This is used in acknowledging receipt of informational Submittals that address means and methods of construction such as schedules and work plans, conformance test reports, health and safety plans, etc. Feedback regarding missing information, conflicting information, or other information that makes it incomplete can be made with comments.

B. Vendor: Prepare resubmittal, if applicable:
1. Clearly identify each correction or change made. Provide page references to the changed information within the resubmittal.
2. Include a response in writing to each of the Engineer's comments or questions for Submittal packages that are resubmitted in the order that the comments or questions were presented from the first and subsequent Submittals and numbered consistent with the Engineer's numbering.
a. Acceptable responses to the Engineer's comments are listed below:
1) "Incorporated" - Engineer's comment or change is accepted and appropriate changes are made.
2) "Response" - Engineer's comment not incorporated. Explain why comment is not accepted or requested change is not made. Explain how requirement will be satisfied in lieu of comment or change requested by the Engineer.

b. Reviews and resubmittals:
1) Vendor shall provide resubmittals which include responses to all Submittal review comments separately and at a level of detail commensurate with each comment.
2) Vendor responses shall indicate how the Vendor resolved the issue pertaining to each review comment:
a) Responses such as "acknowledged" or "noted" are not acceptable.
3) Resubmittals which do not comply with this requirement may be rejected and returned without review.

4) Vendor shall be allowed no extensions of any kind to any part of their contract due to the rejection of non-compliant Submittals.
5) Submittal review comments not addressed by the Vendor in resubmittals shall continue to apply whether restated or not in subsequent reviews until adequately addressed by the Vendor to the satisfaction of the reviewing and approving authority.

c. Any resubmittal that does not contain responses to the Engineer's previous comments shall be returned for revision and resubmittal. No further review by the Engineer will be performed until a response for previous comments has been received.

3. Resubmittal timeframe:
   a. Vendor shall provide resubmittal within 15 days.
   b. When a resubmittal cannot be returned within the specified period, Vendor shall notify the Engineer in writing.
4. Review costs:
   a. Costs incurred by the Owner as a result of additional reviews of a particular Submittal after the second time it has been reviewed shall be borne by the Vendor.
   b. Reimbursement to the Owner will be made by deducting such costs from the Vendor's subsequent progress payments.

## 1.07 PRODUCT DATA

A. Edit Submittals so that the Submittal specifically applies to only the product furnished.

B. Neatly cross out all extraneous text, options, models, etc., that do not apply to the product being furnished so that the information remaining is only applicable to the product being furnished.

## 1.08 SHOP DRAWINGS

A. Indicate project-designated equipment tag numbers for Submittal of devices, equipment, and assemblies.

## 1.09 SAMPLES

A. Details:
   1. Submit labeled samples.
   2. Samples will not be returned.
   3. Provide number of sample Submittals as below:
      a. Total: 3 minimum.
         1) Owner: 1.
         2) Engineer: 2.
         3) Vendor: None.

## PART 2 PRODUCTS (NOT USED)

## PART 3 EXECUTION (NOT USED)

END OF SECTION

## ATTACHMENT A - VENDOR SUBMITTAL TRANSMITTAL FORM

## VENDOR SUBMITTAL TRANSMITTAL FORM

| | | | |
|---|---|---|---|
| **Owner:** | Click here to enter text. | **Date:** | MM/DD/YYYY |
| **Vendor:** | Click here to enter text. | **Project No.:** | XXXXX.XX |
| **Project Name:** | Click here to enter text. | **Submittal Number:** | 000 |
| **Submittal Title:** | Click here to enter text. | | |
| **To:** | Click here to enter text. | | |
| **From:** | Click here to enter text. | Click here to enter text. | |
| | Click here to enter text. | Click here to enter text. | |

| **Specification No. and Subject of Submittal/Equipment Supplier** | | | |
|---|---|---|---|
| **Spec ##:** | Spec ##. | **Subject:** | Click here to enter text. |
| **Authored By:** | Click here to enter text. | **Date Submitted:** | XX/XX/XXXX |

| **Submittal Certification** | | |
|---|---|---|
| **Check Either (A) or (B):** | | |
| ☐ | (A) | We have verified that the equipment or material contained in this Submittal meets all the requirements specified in the project manual or shown on the Contract Drawings with no exceptions. |
| ☐ | (B) | We have verified that the equipment or material contained in this Submittal meets all the requirements specified in the project manual or shown on the Contract Drawings, except for the deviations listed. |
| Certification Statement: By this Submittal, I hereby represent that I have determined and verified all field measurements, field construction criteria, materials, dimensions, catalog numbers and similar data, and I have checked and coordinated each item with other applicable approved Shop Drawings and all Contract requirements. | | |
| **Vendor's Reviewer's Signature:** | | |
| **Printed Name:** | | |

| **PM/CM Office Use** | |
|---|---|
| Date Received Vendor to PM/CM: | |
| Date Received PM/CM to Reviewer: | |
| Date Received Reviewer to PM/CM: | |
| Date Sent PM/CM to Vendor: | |

# SECTION 01_35_73

# DELEGATED DESIGN PROCEDURES

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Delegated Design procedures.

### 1.02 GENERAL

A. Delegated Design - Professional design services assigned to the Vendor by express delegation in the Contract Documents. Work is “Delegated Design” where the Technical Sections require the Vendor to provide professional design services and to submit signed and sealed documents from a registered Professional Engineer.

B. Vendor’s Professional Engineer - The design professional retained by the Vendor to perform Delegated Design.

C. Owner may require Vendor to provide professional design services for a portion of the Work by express delegation in the Contract Documents.
   1. Requirements of Delegated Design component as specified in the Technical Section and as indicated on the Drawings.
   2. Such delegation will specify the performance and design criteria that such services must satisfy, and the Submittals that the Vendor must furnish to the Engineer with respect to the Delegated Design.

D. Vendor shall cause such Delegated Design services to be provided pursuant to the professional standard of care by a properly licensed design professional, whose signature and seal shall appear on Drawings, calculations, Specifications, certifications, and Submittals prepared by such design professional.
   1. Vendor shall not be responsible for the adequacy of performance or design criteria specified by the Owner or Engineer.
   2. Vendor is not required to provide professional services in violation of applicable Laws and Regulations.
   3. Such design professional shall issue certifications of design required by Laws and Regulations.
   4. If a Shop Drawing or other Submittal related to the Owner-delegated design is prepared by the Vendor, a Subcontractor, or others for submittal to the Engineer, then such Shop Drawing or other Submittal shall bear the written approval of Vendor’s design professional when submitted by the Vendor to the Engineer.

E. Owner and Engineer shall be entitled to rely upon the adequacy, accuracy, and completeness of the services, certifications, and approvals performed or provided by the design professionals retained or employed by Vendor under Delegated Design, subject to the professional standard of care and the performance and design criteria stated in the Contract Documents.

F. Engineer's review, approval, and other determinations regarding design drawings, calculations, Specifications, certifications, and other Submittals furnished by Vendor pursuant to a Delegated Design will be only for the following limited purposes:
   1. Confirming that Submittal is in conformance with the performance and design criteria specified in the Contract Documents.

## 1.03 VENDOR'S PROFESSIONAL ENGINEER

A. Vendor or Subcontractor shall retain a licensed Professional Engineer to perform Delegated Design.

B. Qualifications:
   1. Holding a current license to perform the specified design in the same jurisdiction as the Project Site.
   2. Experienced in designing similar systems of similar complexity.

C. Insurance:
   1. Provide as required by the Contract Documents.

D. Responsibilities:
   1. Review and design in accordance with system performance and design criteria stated in the Contract Documents.
      a. Prepare written requests for clarifications or interpretations of performance or design criteria for submittal to the Engineer by the Vendor.
   2. Sign and seal design reports, calculations, design drawings and specifications, and other design Submittals for the Delegated Design Work.
   3. Review and submit written approval of Submittals related to the Delegated Design Work.
   4. Design modifications to the Delegated Design Work as required.
   5. Visit the Site, as required, to verify that installation of the Delegated Design Work is in conformance with the Delegated Design Drawings and Specifications.
   6. Submit through Vendor to Engineer written, signed, and sealed certification that the installed Delegated Design Work complies with Vendor's Professional Engineer's design.

## 1.04 SUBMITTALS

A. Prior to the start of Delegated Design:
   1. Vendor's Professional Engineer's qualifications:
      a. Experience for the Delegated Design.
      b. Evidence of Professional Engineering license.
   2. Vendor's Professional Engineer Professional Liability Insurance certificate.

B. Delegated Design:
    1. Product data:
        a. Details related to the Delegated Design as specified in Technical Sections to completely describe the system.
    2. Design documents with signature and seal from the Vendor's Professional Engineer.
        a. Design documents include, but are not limited to, Drawings, calculations, Specifications, inspection reports, and certifications.
    3. Lists and schedules:
        a. Prepare and submit lists or schedules of items where Delegated Design is required by the Contract Documents.

C. Construction services:
    1. Vendor's Professional Engineer's comments on Submittals.
    2. Other construction documents, as required.

## 1.05 ENGINEER RESPONSE TO DELEGATED DESIGN SUBMITTALS

A. Engineer response will be either of the following:
    1. Approved:
        a. Vendor may proceed with the Work.
        b. Review was for the limited purpose of determining that the document was stamped by a Professional Engineer and that such design is generally consistent with and will not negatively affect the design concept presented in the Contract Documents.
    2. Make Corrections Noted - See Comments:
        a. Vendor may proceed with the Work; however, all notations and comments must be incorporated into the final product.
        b. Review was for the limited purpose of determining that the document was stamped by a Professional Engineer and that such design is generally consistent with and will not negatively affect the design concept presented in the Contract Documents.
    3. Rejected - See Remarks:
        a. Vendor may not proceed with the Work described in the Submittal.
        b. Submittal does not meet the intent of the Contract Documents.
        c. Resubmittal of complete Submittal package is required with materials, equipment, methods, etc., that meet the requirements of the Contract Documents.

## PART 2 PRODUCTS (NOT USED)

## PART 3 EXECUTION (NOT USED)

END OF SECTION

## SECTION 01_41_00

## REGULATORY REQUIREMENTS

### PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Regulatory authorities and codes.

### 1.02 AUTHORITIES HAVING JURISDICTION (AHJ)

A. Authorities Having Jurisdiction (AHJ) for work within Larimer County:
   1. Also referred to as the permitting agency.
   2. Building Department: Larimer County.
   3. Fire Department: Poudre Fire Authority.

B. Applicable codes for work within Larimer County:
   1. International Code Council (ICC).
      a. Building code:
         1) International Building Code (IBC), 2021.
            a) Local amendments per Larimer County.
         2) International Existing Building Code (IEBC), 2021.
            a) Local amendments per Larimer County.
      b. Electrical code:
         1) National Fire Protection Association (NFPA), NFPA 70.
         2) National Electrical Code (NEC), 2023.
            a) Local amendments per Larimer County.
      c. Energy code:
         1) International Energy Conservation Code (IECC), 2021.
         2) Local amendments per Larimer County.
      d. Fire code:
         1) International Fire Code (IFC), 2021.
         2) Local amendments per Larimer County.
      e. Mechanical code:
         1) International Mechanical Code (IMC), 2021.
         2) Local amendments per Larimer County.

### PART 2 PRODUCTS (NOT USED)

### PART 3 EXECUTION (NOT USED)

END OF SECTION

# SECTION 01_60_01

# PRODUCT REQUIREMENTS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Requirements for products.

### 1.02 TERMINOLOGY

A. The words and terms listed below, are not defined terms that require initial capital letters, but, when this Section is referenced in other Specifications, have the indicated meaning:
   1. Special tools:
      a. Special wrenches, gauges, circuit setters, and other similar devices required for the proper operation or maintenance of a system that would not normally be in the Owner's tool kit and that have been specifically made for use on a product for assembly, disassembly, repair, or maintenance.

### 1.03 SHIPMENT

A. Prepare products for shipment by:
   1. Tagging or marking to match the Shop Drawings or Contract Documents.
   2. Including complete packing lists and bills of material with each shipment.
   3. Packaging products to facilitate handling and protection against damage during transit, handling, and storage.
   4. Securely attach special instructions for proper field handling, storage, and installation before packaging and shipment.

B. Transport products by methods that avoid product damage.

C. Deliver products in undamaged condition in the manufacturer's unopened packaging.

### 1.04 STORAGE

A. Storage is the responsibility of the installing contractor.

## PART 2 PRODUCTS

### 2.01 GENERAL REQUIREMENTS

A. Provide products by the same manufacturer when units are of similar nature, unless otherwise specified.

B. Provide like parts of duplicate units that are interchangeable.

C. Provide equipment or products that have not been in service prior to delivery, except as required by tests.

D. For products or workmanship specified by association, trade, or other consensus standards, comply with requirements of the standard, except when more rigid requirements are specified or are required by applicable codes.
   1. Conform to reference standard by date of issue current on date of Contract Documents, except where specific date is established by code.

E. Provide products produced by manufacturers regularly engaged in the production of these products.

F. Provide products that bear approvals and labels as specified such as Factory Mutual (FM), Underwriters Laboratory (UL), or National Sanitation Foundation (NSF International) that are acceptable to the Authority Having Jurisdiction.

## 2.02 MATERIAL

A. Dissimilar metals:
   1. Separate contacting surfaces with dielectric material.
   2. Neoprene, bituminous impregnated felt, heavy bituminous coatings, nonmetallic separators, washers, petrolatum tape, or other materials as specified.
   3. Dielectric coatings can be used to separate dissimilar metal couples from surrounding environment if isolation of metals is not possible, with approval of the Engineer.

B. Edge grinding:
   1. Sharp projections of cut or sheared edges of ferrous metals which are not to be welded shall be ground to a radius required to ensure satisfactory paint adherence and mitigate any safety hazard.
   2. A surface profile will need to be re-established for coating adherence based on coating manufacturer's profile requirements.

C. Use anti-galling compound on threads of stainless steel fasteners during factory assembly.

D. Provide anti-galling compound with stainless steel fasteners shipped for field assembly.

E. Aluminum in contact with concrete or masonry: Apply epoxy mastic.

## 2.03 PRODUCT SELECTION

A. When products are specified with names of manufacturers but no model numbers or catalog designations, provide products by one of the named manufacturers that meet or exceed specifications.

B. When products are specified with names of manufacturers and model numbers or catalog designations, provide products with model numbers or catalog designations by one of the named manufacturers.

C. When products are specified with names of manufacturers, but with brand or trade names, model numbers, or catalog designations by one manufacturer only, provide:
   1. Products specified by brand or trade name, model number, or catalog designation.
   2. Products by another named manufacturer proven, in accordance with requirements for an “or equal”, including the Engineer’s approval, to meet or exceed quality, appearance and performance of specified brand or trade name, model number, or catalog designation.

D. When products are specified with only one manufacturer followed by “or equal,” provide:
   1. Products meeting or exceeding specifications by specified manufacturer.
   2. Engineer deemed “or equal” evidenced by an approved Shop Drawing or other written communication.

E. When products are specified by naming 2 or more manufacturers with 1 manufacturer as a “Basis of Design”:
   1. Any of the named manufacturers can be submitted.
   2. If the product submitted is not by the named “Basis of Design” product and requires a change in the scope (dimensions, configuration, physical properties, etc.), schedule (longer lead time), or budget, the Vendor must submit a substitution request.

## PART 3 EXECUTION (NOT USED)

END OF SECTION

## SECTION 01_75_17

## COMMISSIONING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Commissioning.

### 1.02 DEFINITIONS

A. Commissioning: The process of planning for, testing of, and start-up of systems, subsystems, equipment, components, and devices of the Work to demonstrate, through documented verification, that the Work has successfully met the Contract Documents. It includes training the Owner's staff on operation and maintenance of the installed Work.

B. Commissioning Phases: The activities of commissioning are grouped into the phases defined in the following table.
   1. Table 1 - Commissioning Phases.

| TABLE 1 - COMMISSIONING PHASES | | |
|---|---|---|
| **Planning Phase** | **Testing and Training Phase** | **Start-Up Phase** |
| Draft Test Plans | Source Testing:<br>• Documentation | Start-Up:<br>• Documentation<br>• Owner Training |
| | Installation Verification:<br>• Documentation<br>• Owner Training | |
| | Functional Testing:<br>• Documentation<br>• Owner Training | |

C. Component: A part of a system that does not have an electrical connection or internal electronics. Examples: Piping and pressure gauges.

D. Device: A part of a system that has electrical connections or internal electronics. Examples: Level transmitter or pressure transmitter.

E. Equipment: A factory or field assembled apparatus that performs an identifiable function. Examples: Pumps, motors, VFDs, MCCs.

F. Functional Testing: Testing performed on a completed subsystem or system to demonstrate that the system meets the specified requirements. Example systems: Backwash system, dewatering system.

G. Installation Verification: Testing to demonstrate that equipment or system and associated components or devices have been properly installed. Example equipment: Pumps, meters, and blowers with associated piping.

H. Manufacturer's Certificate of Functional Compliance: The form completed by the manufacturer to confirm that testing of the installed equipment or system has been performed and the results conform to the specified performance. The form is provided in Attachment C provided at the end of this Section.

I. Manufacturer's Certificate of Installation Verification: The form completed by the manufacturer to confirm that the equipment or system is installed in conformance with the Contract. The form is provided in Attachment B at the end of this Section.

J. Manufacturer's Certificate of Source Testing: The form completed by the manufacturer to confirm that the specified source tests have been performed and the results conform to the specified requirements. The form is provided in Attachment A at the end of this Section.

K. Owner Training: The Owner's staff is trained by the Contractor, with assistance from manufacturer, to operate and maintain the completed Work. This is sometimes referred to as Vendor Specific Training.

L. Source Testing: Test equipment or products for performance at point of manufacture or assembly for the requirements specified in the Contract Documents. Also referred to as factory testing and factory acceptance testing (FAT).

M. Start-Up: Operating the Work with process water to verify the Work meets the Contract Documents.

N. Start-Up Phase: The phase when Start-Up occurs.

## 1.03 SUBMITTALS

A. Project Commissioning:
   1. Schedules:
      a. Owner Training Schedule.
   2. Test Reports:
      a. Submit draft Test Reports outline in the Planning Phase, unless specified otherwise.
         1) Engineer approval of draft Test Reports outline required for successful completion of Planning Phase.
      b. Submit final Test Report a maximum of 30 calendar days after testing.

B. Technical Sections Commissioning:
   1. Manufacturer's representative's qualifications.
      a. Submit to Engineer no later than 30 days in advance of required services.
      b. Representative's name, phone, and e-mail address:
         1) May use 2 representatives: 1 for field testing and 1 for Owner Training.
         2) Provide resume stating instructor's technical expertise and instructional technology skills and experience.

2. Test Plans:
    a. Submit draft Test Plan outlined in the Planning Phase, unless specified otherwise.
        1) Engineer approval of draft Test Plans required for successful completion of Planning Phase.
    b. Submit final Test Plan a minimum of 90 calendar days prior to testing.
    c. Engineer approval of final Test Plan required prior to start of testing.
3. Test Reports:
    a. Submit draft Test Reports outline in the Planning Phase, unless specified otherwise.
        1) Engineer approval of draft Test Reports outline required for successful completion of Planning Phase.
    b. Submit final Test Report a maximum of 30 calendar days after testing.
4. Manufacturer's representatives field notes and data.
5. Owner Training:
    a. Prior to the training session:
        1) Training instructor qualifications.
        2) Training course materials: Due 30 calendar days prior to initial training session.
            a) Drafts of training agenda, lesson plan, presentation, handouts, and list of audio-visual aids.
            b) Format: 1 electronic copy in the format specified by the Owner and 3 hard copies organized in notebooks.

## 1.04 MANUFACTURER'S REPRESENTATIVES

A. Qualifications: As specified below and in the Technical Sections:
    1. For Installation and Functional Testing:
        a. Factory trained and experienced in the technical applications, installation, operation, and maintenance of respective equipment/system with full authority by the equipment/system manufacturer to issue the certifications required of the manufacturer.
    2. Training instructor qualifications:
        a. Provide resume stating instructor's technical preparation and instructional technology skills and experience.
        b. Knowledgeable in the equipment/system for which they are training.
        c. Experienced in conducting classes.
        d. Sales representatives are not qualified instructors unless they possess the detailed operating and maintenance knowledge required for proper class instruction.
    3. Representatives to be approved by Owner and Engineer.
    4. No substitute representatives without written approval by Owner and Engineer.

B. Duties:
    1. Determine if additional time and/or trips (beyond those specified in the Technical Sections) is required to perform the specified services.
    2. Coordinate services in accordance with the installing contractor's Project schedule, up to and including making multiple trips to the Project Site when there are separate milestones associated with installation of each occurrence of manufacturer's equipment.

3. Perform on-site services as specified in the Technical Sections.
4. Provide daily copies of manufacturer's representatives field notes and data to Contractor.

## 1.05 PLANNING PHASE

A. Overview of Planning Phase:
   1. Obtain Engineer approval of draft Test Plans.

B. Test Plans.
   1. Source Test (Factory Acceptance Test):
      a. As specified in this Section and other Technical Sections.
      b. Based on approved Shop Drawings.
      c. Prepared by the Vendor.
      d. Include the following items for each test:
         1) Purpose of the test.
         2) Identification of each item of equipment/system to be tested, including system designation, location, tag number, control loop identifier, etc.
         3) Description of the pass/fail criteria that will be used.
         4) Listing of pertinent reference documents (Contract and industry standards or sections applicable to the testing).
            a) Credentials of test personnel.
         5) Test equipment:
            a) Include Product Data for the test equipment.
            b) Appropriate calibration records.
               (1) Drawings or photographs of test stands and/or test apparatus.
         6) Duration: Determine test durations with Owner's input.
         7) Detailed step-by-step test procedures.
            a) Level of detail shall be sufficient for the witness to follow the steps.
      e. Furnish labor, power, tools, equipment, instruments, and services required for and incidental to testing activities.
   2. Test forms minimum requirements:
      a. Name of product to be tested.
      b. Test date.
      c. Names of persons conducting the test.
      d. Names of persons witnessing the test, where applicable.
      e. Test data.
      f. Applicable project requirements as specified in the Technical Sections.
      g. Check offs for each completed test or test step.
      h. Place for signature of person conducting tests and for the witnessing person, as applicable.

## 1.06 TESTING AND TRAINING PHASE

A. Overview of Testing and Training Phase:
   1. General:
      a. Vendor to support installing contractor in testing the Work to verify it meets the Contract requirements.
      b. Vendor trains the Owner to operate and maintain the Work.

B. Source Testing:
   1. As specified in the Technical Section.
   2. Source Test Plan:
      a. Engineer approval of Source Test Plan required prior to testing.
   3. Witnessed in person:
      a. If specified in the Technical Section, Vendor shall coordinate testing dates and schedule with Owner and Engineer. Owner's and Engineer's in person witness of testing is at their discretion. The Vendor shall make accommodations for virtual witness testing in lieu of in person testing if requested by Owner or Engineer.
   4. Virtual witness testing:
      a. As specified in the Technical Sections.
      b. Vendor is responsible for costs associated with virtual witness.
      c. Provide the following:
         1) An agenda detailing start time of each major phase in the procedure defined in the approved Test Plan.
         2) A dedicated operator (separate from the test technician) to operate the camera, provide commentary throughout test, and inspect devices at the request of the attendees.
      d. Online meeting platform: Microsoft Teams.
      e. Share video through a high-definition camera.
      f. Establish methods to communicate, convey, and record information clearly even in environments with loud background noise.
         1) Electronic feed for screen sharing of the control panel, HMI, or other screens used throughout testing.
         2) Provide recording of virtual sharing within 1 day after testing.
      g. Test run of virtual sharing a minimum of 1 week prior to the test:
         1) Use current record documents in PDF format.
         2) Provide recording of virtual sharing within 1 day after the test run.
         3) Engineer approval of test run virtual sharing is required before Source Testing.
   5. If the Source Test is not ready on the scheduled date or if the Source Test fails:
      a. Vendor is responsible for associated costs:
         1) First test costs that are non-refundable, if applicable.
         2) Repeat test costs:
            a) Trip costs, if applicable.
         3) Virtual witness costs, if applicable.
   6. Source Testing is complete after successful testing, submittal of test report, and Manufacturer's Certificate of Source Testing.
   7. Engineer approval of Source Testing Report is required.

C. Installation Verification:
   1. Overview:
      a. Verifying the installation of equipment to be in accordance with Manufacturer's Instructions.
   2. Prerequisite:
      a. Engineer approval of Source Testing Report.
   3. Submit Manufacturer's Certificate of Installation Verification.
   4. Engineer approval of Manufacturer's Certificate of Installation Verification is required.

D. Documentation:
   1. Provide records generated during Commissioning Phase of Project, including, but not limited to:
      a. Training documentation.
      b. Manufacturer's Certificate of Source Testing.
      c. Manufacturer's Certificate of Installation Verification.
      d. Manufacturer's Certificate of Functionality Compliance.
      e. Test forms and documentation.
      f. Logs of time spent by manufacturer's representatives performing services on the job site.
   2. Engineer approval of documentation is required.

E. Owner Training:
   1. Train Owner's staff on the operation and maintenance of the equipment/system.
   2. Train on each topic of the approved Operation and Maintenance Manual.
      a. Include classroom instruction and field demonstration with all necessary tools and test equipment.
   3. Training tailored to the skills and job classifications of the staff attending the classes (e.g., plant superintendent, treatment plant operator, maintenance technician, electrician, etc.).
   4. Training outcomes:
      a. Owner's staff can safely operate, maintain, and repair the equipment/systems provided as recommended by the manufacturer.
   5. Training plan:
      a. Manufacturer's representatives to provide both classroom-based learning and field (hands-on) training, based on training module content and stated learning objectives.
      b. Conduct classroom training at location designated by Owner.
      c. Scope and sequence:
         1) Plan and schedule training in the correct sequence to provide prerequisite knowledge and skills to trainees.
            a) Describe recommended procedures to check/test equipment/system following a corrective maintenance repair.
         2) If multiple classes are needed to meet the training objectives, they shall be included in the training plan.
   6. Owner Training Schedule:
      a. Schedule Owner's staff training within the constraints of their workloads.
         1) Those who will participate in this training have existing full-time work assignments, and training is an additional assigned work task, therefore, scheduling is imperative.

2) Owner staff work schedules regularly shift, as treatment facilities are typically operated on an around-the-clock basis.
3) Maximum training hours per week: 4.
4) Days available for training:
a) Monday to Friday.

b. Training scheduling coordination:
1) Complete Owner Training no sooner than 15 calendar days prior to Functional Testing of each system.

c. Class logistics:
1) Delivery time minimum: 2 hours.
2) Delivery time maximum: 4 hours.
3) Class agenda:
a) Refreshment break: One 10-minute break.
b) Meal break: One 45-minute break, unless otherwise specified.
c) Schedule refreshment breaks and meal breaks to meet the class needs and Owner work rules.
4) Schedule specific sessions:
a) Minimum of 30 days in advance to allow Owner staffing arrangements to take place.
b) At the times requested by the Owner, within the period 7 a.m. to 7 p.m. Monday through Friday.
(1) Times scheduled will be at Owner's discretion.
c) Owner approval and confirmation required for session schedules.
d) Provide minimum of 2 sessions for each class unless otherwise noted.
(1) The purpose of having multiple sessions on each class is to accommodate the attendance of as many Owner personnel working different shifts as possible.
e) A maximum of 1 session per day for each class.

d. Number of students:
1) Estimated class size maximum: 10 staff.
2) Engineer will confirm the headcount 1 week prior to the class so that the instructor can provide the correct number of training aids for students.

7. Submittals:
a. Submit Training Plan Schedule 60 calendar days before the first scheduled training session, including, but not limited to, lesson plans, participant materials, instructor's resumes, and training delivery schedules.
b. Submit training documentation, including the following:
1) Training plan:
a) Training modules.
b) Scope and sequence statement.
c) Contact information for manufacturer's instructors. including name, phone, and e-mail address.
d) Instructor qualifications.
2) Training program schedule:
a) Format: Bar chart:
(1) Include in the Project Progress Schedule.
b) Contents:
(1) Training modules and classes.

8. Lesson plans:
    a. Divide training into discrete modules appropriate for the equipment and trades.
    b. State performance-based learning objectives in terms of what the trainees will be able to do at the end of the lesson.
    c. Define student conditions of performance and criteria for evaluating instructional success.
    d. Minimum requirements:
        1) Hands-on demonstrations planned for the instructions.
        2) Cross-reference training aids.
        3) Planned training strategies such as whiteboard work, instructor questions, and discussion points or other planned classroom or field strategies.
        4) Attach handouts cross-referenced by section or topic in the lesson plan.
        5) Indicate duration of outlined training segments.
    e. Provide instruction lesson plans for each trade:
        1) Detailed component description:
            a) Identify each component function and describe in detail.
            b) Identify equipment's mechanical, electrical, and electronic components and features.
            c) Where applicable, group relative components into subsystems.
            d) Identify and describe in detail equipment safety features, permissive and controls interlocks.
        2) Equipment operation:
            a) Describe equipment's operating (process) function and system theory.
            b) Describe equipment's fundamental operating principles and dynamics.
            c) Identify support equipment associated with the operation of subject equipment.
            d) Detail the relationship of each piece of equipment or component to the subsystems, systems, and process.
            e) Cite hazards associated with the operations, exposure to chemicals associated with the component, or the waste stream handled by the component.
            f) Specify appropriate safety precautions, equipment, and procedures to eliminate, reduce, or overcome hazards.
        3) Define Preventative Maintenance (PM) inspection procedures required on equipment in operation, spot potential trouble symptoms (anticipate breakdowns), and forecast maintenance requirements (predictive maintenance).
            a) Review preventive maintenance frequency and task analysis table.
        4) Define equipment Corrective Maintenance (CM) troubleshooting:
            a) Describe recommended equipment preparation requirements as they relate to specific craft problems.
            b) Identify and describe the use of any special tools required for maintenance of the equipment as they relate to specific craft problems.

c) Provide component specific troubleshooting checklists as they relate to specific craft problems.
d) Describe component removal/installation and disassembly/assembly procedures for specific craft repairs.
e) Perform at least 2 hands-on demonstrations of common corrective maintenance repairs.

5) Describe recommended measuring instruments and procedures, and provide instruction on interpreting alignment measurements, as appropriate.

9. Training instruction format:
   a. Training for operations and maintenance personnel shall be provided as one entity.
   b. Instructors shall apply adult education best practices, emphasizing learner participation and activity.
   c. Lecturing should be less than 30 percent of class time.
   d. Training delivery may include problem solving, question/answer, hands-on instruction, practice, evaluation/feedback tools, and lecture to support training objectives.
   e. Conduct hands-on instruction according to the following descriptions:
      1) Present hands-on demonstrations of at least the following tasks:
         a) Proper start-up, shutdown, and normal and alternative operating strategies.
         b) Common corrective maintenance repairs for each group.
         c) Recommended procedures to check/test equipment/system following a corrective maintenance repair.
         d) Preventative maintenance points.
         e) Calibration, if applicable.
      2) Use tools and equipment provided by manufacturer to conduct the demonstrations.
         a) Submit requests for supplemental assistance and facilities with the Vendor and Contractor's proposed lesson plans.
      3) Vendor and Contractor remain responsible for equipment disassembly or assembly during hands-on training situations involving equipment disassembly or assembly by Owner's personnel.
   f. Training aids:
      1) Instructors shall provide needed audio-visual devices such equipment (televisions, video recorder/player, computer, projectors, screens, easels, etc.), models, charts, etc., for each class.
      2) Instructor to confirm with Engineer in advance of each class that the classroom will be appropriate for the types of audiovisual equipment to be employed.
10. Training sessions:
    a. Provide training sessions for equipment/system as specified in the individual equipment/system section.
    b. Include the following information in the agenda:
       1) Instructor name.
       2) Listing of subjects to be discussed.
       3) Time estimated for each subject.
       4) Allocation of time for Owner staff to ask questions and discuss the subject matter.
       5) List of documentation to be used or provided to support training.

c. Owner may request that particular subjects be emphasized, and the agenda be adjusted to accommodate these requests.
d. Digitally record audio and video of each training session.
    1) Include classroom and field instruction with question and answering periods.
    2) Engineer approval required for producer of video materials from one of the following options:
        a) Qualified, professional video production company or individual.
    3) Record in digital format and recording shall become property of the Owner with exclusive rights.
        a) No video recording agreements will be entered into by the Owner.
    4) Media:
        a) Video quality shall be 720p HD or greater in MPG, AVCHD, AVI, or MP4 format.
        b) Digital color video format.
        c) Provide audio portion of the composite CD sufficiently free from electrical interference and background noise to provide complete intelligibility of oral report.
        d) Identification: On each copy provide a label with the following information:
            (1) Name of training.
            (2) Date video was recorded.
        e) Display continuous running time.
        f) At start of each video recording, record training class name, date, and instructor's name.
        g) Provide audio quality that is not degraded during the recording of the field sessions due to background noise, space, distance or other factors.
    5) Vendor and Contractor shall provide a written release from all claims to the recorded training material produced, if required.
e. Distribute copies of the agenda to each student at the beginning of each training class.
f. Trainees will keep training materials and documentation after the session.
g. Distribute Training Evaluation Form following each training session.
    1) Training Evaluation Form is included in this Section.
    2) Return completed Training Evaluation Forms to Owner's designated training coordinator immediately after session is completed.
    3) Revise training sessions judged "Unsatisfactory" by a majority of attendees.
        a) Conduct training sessions again until a satisfactory rating is achieved.

11. Engineer approval of Owner Training is required.

## 1.07 START-UP PHASE

A. Overview of Start-Up Phase:
    1. General:
        a. Vendor to support Owner with operation of Vendor provided equipment to meet contract requirements.

B. Start-Up Period:
   1. Vendor responsibilities:
      a. Provide support and troubleshooting for Vendor provided equipment.
   2. Prerequisites:
      a. Engineer approval of Testing and Training Phase.

## PART 2 PRODUCTS (NOT USED)

## PART 3 EXECUTION (NOT USED)

END OF SECTION

## ATTACHMENT A - MANUFACTURER'S CERTIFICATE OF SOURCE TESTING

## MANUFACTURER'S CERTIFICATE OF SOURCE TESTING

OWNER _____ EQPT/SYSTEM _____

PROJECT NAME _____ EQPT TAG NO. _____

PROJECT NO. _____ EQPT SERIAL NO. _____

SPECIFICATION NO. _____

SPECIFICATION TITLE _____

Comments: _____

_____

_____

_____

_____

I hereby certify Source Testing has been performed on the above-referenced equipment/system as defined in the Contract, and results conform to the Contract Document requirements. Testing data is attached.

Date of Execution: _____, 20 _____

Manufacturer: _____

Manufacturer's Authorized Representative Name *(print)*: _____

_____

(Authorized Signature)

If applicable, Witness Name *(print)*: _____

_____

(Witness Signature)

## ATTACHMENT B - MANUFACTURER'S CERTIFICATE OF INSTALLATION VERIFICATION

## MANUFACTURER'S CERTIFICATE OF INSTALLATION VERIFICATION

OWNER _____ EQPT/SYSTEM _____

PROJECT NAME _____ EQPT TAG NO. _____

PROJECT NO. _____ EQPT SERIAL NO. _____

SPECIFICATION NO. _____

SPECIFICATION TITLE _____

I hereby certify the installation of the above-referenced equipment/system as defined in the Contract Documents.

NOTES:

1. Attach written certification report prepared by and signed by the electrical and/or instrumentation subcontractor.

Comments: _____

_____

I, the undersigned manufacturer's representative, hereby certify that I am (i) a duly authorized representative of the manufacturer, (ii) empowered by the manufacturer to inspect, approve, and operate this equipment/system, and (iii) authorized to make recommendations required to ensure that the equipment/system furnished by the manufacturer is complete and operational, except as may be otherwise indicated herein. I further certify that all information contained herein is true and accurate.

Date: _____

Manufacturer: _____

Manufacturer's Authorized Representative Name *(print)*: _____

By Manufacturer's Authorized Representative: _____

(Authorized Signature)

## ATTACHMENT C - MANUFACTURER'S CERTIFICATE OF FUNCTIONAL COMPLIANCE

## MANUFACTURER'S CERTIFICATE OF FUNCTIONAL COMPLIANCE

OWNER _____ EQPT/SYSTEM _____

PROJECT NAME _____ EQPT TAG NO. _____

PROJECT NO. _____ EQPT SERIAL NO. _____

SPECIFICATION NO. _____

SPECIFICATION TITLE _____

I hereby certify the Functional Testing of the above-referenced equipment/system as defined in the Contract Documents.

NOTES:

1. Attach test results with collected data and test report.
2. Attach written certification report prepared by and signed by the electrical and/or instrumentation subcontractor.

Comments: _____

_____

I, the undersigned manufacturer's representative, hereby certify that I am (i) a duly authorized representative of the manufacturer, (ii) empowered by the manufacturer to inspect, approve, and operate this equipment/system, and (iii) authorized to make recommendations required to ensure that the equipment/system furnished by the manufacturer is complete and operational, except as may be otherwise indicated herein. I further certify that all information contained herein is true and accurate.

Date: _____

Manufacturer: _____

Manufacturer's Authorized Representative Name *(print)*: _____

By Manufacturer's Authorized Representative: _____

(Authorized Signature)

WITNESSES:

By Owner's Authorized Representative: _____

(Authorized Signature)

By Engineer's Authorized Representative: _____

(Authorized Signature)

## ATTACHMENT D - TRAINING EVALUATION FORM

## TRAINING EVALUATION FORM

EQUIPMENT/SYSTEM ITEM: _____

VENDOR/MANUFACTURER: _____

DATE: _____ NAME OF REPRESENTATIVE: _____

| | | | | | |
|---|---|---|---|---|---|
| 1. | Was representative prepared? | Acceptable | Unacceptable | or | N/A |
| 2. | Was an overview description presented? | Acceptable | Unacceptable | or | N/A |
| 3. | Were specific details presented for system components? | Acceptable | Unacceptable | or | N/A |
| 4. | Were alarm and shutdown conditions clearly presented? | Acceptable | Unacceptable | or | N/A |
| 5. | Were step-by-step procedures for starting, stopping, and troubleshooting presented? | Acceptable | Unacceptable | or | N/A |
| 6. | Were routine/preventative maintenance items clearly identified? | Acceptable | Unacceptable | or | N/A |
| 7. | Was the lubrication schedule (if any) discussed? | Acceptable | Unacceptable | or | N/A |
| 8. | Was the representative able to answer all questions? | Acceptable | Unacceptable | or | N/A |
| 9. | Did the representative agree to research and answer unanswered questions? | Acceptable | Unacceptable | or | N/A |
| 10. | Comments: _____ | | | | |
| | _____ | | | | |
| | _____ | | | | |
| | _____ | | | | |
| 11. | Overall Rating | Satisfactory | Unsatisfactory | | |

Note:

Sessions judged “Unsatisfactory” by a majority of attendees shall be revised and conducted again until a satisfactory rating is achieved.

## ATTACHMENT E- COMMISSIONING ROLES AND RESPONSIBILITIES MATRIX

## COMMISSIONING ROLES AND RESPONSIBILITIES MATRIX

| NO. | TASK | OWNER | VENDOR | INSTALLING CONTRACTOR | ENGINEER |
|---|---|---|---|---|---|
| | **Testing and Training Phase** | | | | |
| | **Source Testing** | | | | |
| | Source Testing | Witnessed as specified in the Technical Sections. | Lead | No Action | Witnessed as specified in the Technical Sections.<br>Review |
| | Manufacturer's Certificate of Source Testing | No Action | Lead | No Action | Review |
| | **Installation Verification** | | | | |
| | Structural Anchorage Check | Witness | No Action | Lead | Review |
| | Health and Safety Check | Witness | No Action | Lead | Review |
| | Manufacturer Requirements Verification | No Action | Lead | No Action | Review |
| | Contract Documents Verification | No Action | No Action | Lead | Review |
| | Manufacturer's Certificate of Installation Verification | No Action | Lead | No Action | Review |
| | **Functional Testing** | | | | |
| | Checks | Witness | Support | Lead | Witness, Review |
| | Tests | Witness | Support | Lead | Witness, Review |
| | Manufacturer's Certificate of Functional Compliance | No Action | Lead | No Action | Witness, Review |
| | **System Testing** | | | | |
| | System Testing | Witness | Support | Lead | Witness, Review |
| | **Start-Up Phase** | | | | |
| | Start-Up | Lead | Support | Support | Witness, Review |

Legend:

**Lead:** Primarily responsible for organization, coordination, and execution of task work product or result.

**Support:** Assist the lead with organization, coordination, and execution of task work product or result.

**Witness:** Observe and document completion of task work product or result.

**No Action:** Limited or no involvement.

**Review:** Approve for compliance with Contract Documents or reject.

# SECTION 01_78_24

# OPERATION AND MAINTENANCE MANUALS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Preparation and submittal of manual with requirements to operate and maintain the equipment.

### 1.02 ADMINISTRATIVE REQUIREMENTS

A. Sequencing:
   1. Submit draft operation and maintenance manuals prior to shipment of the equipment to the Site.
   2. Submit approved operation and maintenance manuals at least 30 days prior to Functional Testing and at least 60 days prior to Owner Training.
   3. The Vendor shall provide equipment operation and maintenance manuals to the installing contractor for combination into one project operation and maintenance manual.
   4. Make final operation and maintenance manuals available at the Site for use by construction personnel.

### 1.03 SUBMITTALS

A. Furnish Submittals as specified in Section 01_33_00 - Submittal Procedures and the Technical Sections.

B. Draft operation and maintenance manuals:
   1. Quantity:
      a. Electronic copy in portable document format (PDF) format.

C. Final operation and maintenance manuals:
   1. Revised in accordance with the Owner's and Engineer's comments on the draft operation and maintenance manuals, and to include Functional Testing results and certificates.
   2. Quantity:
      a. Electronic copy in PDF format.

D. Spare parts list:
   1. Provide a consolidated spare part list required in accordance with the Technical Specifications.
   2. Engineer and Owner to review list prior to the Contractor's procurement of spare parts.

## 1.04 PREPARATION

A. General requirements:
   1. Provide dimensions in English units.
   2. Assemble material, where possible, in the same order within each volume.
   3. Complete forms on computer; handwriting is not acceptable.
   4. Delete items or clearly mark out options not provided in the supplied equipment.
   5. Cover page shall include the following information:
      a. Operation and maintenance manual.
      b. Equipment name.
      c. Specification Section number.
      d. Equipment tag number s.
      e. Owner's name.
      f. Project number and name.
      g. Date.

B. Electronic requirements:
   1. File format:
      a. Entire manual in PDF.
         1) Include text and drawing information.
         2) Provide a single PDF file.
         3) Create PDF from the native format of the document (Microsoft Word, graphics programs, drawing programs, etc.).
            a) Scanned images are not acceptable.
            b) At file opening, display the entire cover page.
         4) Pagination and appearance to match hard copy.
         5) Ensure that page numbers are included on every page of the document.
         6) Text searchable throughout the entire document, including drawings.
         7) Bookmarks: As specified in Section 01_33_00 - Submittal Procedures.
         8) Thumbnails optimized for fast web viewing.
      b. Drawing requirements:
         1) Provide electronic file with drawings in most current version of AutoCAD format.
         2) White background.
         3) Shapes shall not degrade when closely zoomed.
         4) Screening effects intended to de-emphasize detail in a drawing must be preserved.
   2. Label media with the following information:
      a. Operation and maintenance manual.
      b. Equipment name.
      c. Specification Section number.
      d. Equipment tag number.
      e. Owner's name.
      f. Project number and name.
      g. Date.
   3. If multiple Submittals are made together, each Submittal must have its own subdirectory that is named and numbered based on the Submittal number.

## 1.05 CONTENTS

A. Cover page.

B. Table of Contents: General description of information provided within each tab section.

C. Complete Attachment A - Equipment Summary Form.

D. Completed motor data sheet as specified in Section 26_05_10 – Medium Voltage Motors.

E. Description of system and components.

F. Complete parts list for equipment, including, but not limited to, the following information:
   1. Catalog data: Generic title and identification number of each component part of equipment.
   2. Include bearing manufacturer, model, and ball or roller pass frequencies for every bearing.
   3. Availability.
   4. Service locations.

G. Spare parts list:
   1. Recommended number of parts to be stored at the Site and special storage instructions.

H. Engineering data:
   1. Complete set of 11-inch by 17-inch equipment drawings.
   2. Exploded view or plan and section views with detailed callouts.
   3. Outline, cross-section, and assembly drawings.
   4. System drawings: Provide interconnection and wiring diagrams, plan views, panel layouts, bill of materials, etc.
   5. Packaged equipment system drawings: Provide instrumentation loop drawings, control schematic diagrams, interconnection and wiring diagrams, plan views, panel layouts, bill of materials, etc.
   6. System drawings and data sheets: Include drawings and data furnished by the Engineer and the Vendor; provide “as installed” version.
   7. Provide electrical and instrumentation schematic record drawings.
   8. Information required by the Technical Specifications.

I. Description of equipment function, normal operating characteristics, and limiting conditions.

J. Online resources.

K. Telephone resources.

L. Approved Submittals.
   1. Markup with any field changes.

2. Quality Control Submittals:
    a. Source Testing and Functional Testing test reports and test data.
    b. Manufacturer's certificates.
    c. Performance curves.

M. Start-up procedures: Recommendations for installation, adjustment, calibration, and troubleshooting.

N. Operating procedures:
1. Step-by-step instructions, including, but not limited to, the following:
    a. Safety precautions and applicable safety data sheets.
    b. Guidelines.
    c. Other information as needed for safe system operation and maintenance.

O. Preventative maintenance procedures:
1. Recommended steps and schedules for maintaining equipment.
2. Troubleshooting.

P. Storage instructions.

Q. Lubrication information: Required lubricants and lubrication schedules.

R. Overhaul instructions: Directions for disassembly, inspection, repair and reassembly of the equipment; safety precautions; and recommended tolerances, critical bolt torques, and special tools that are required.

S. Manufacturer's technical reference manuals.

## PART 2 PRODUCTS (NOT USED)

## PART 3 EXECUTION (NOT USED)

END OF SECTION

# ATTACHMENT A - EQUIPMENT SUMMARY FORM

## EQUIPMENT SUMMARY FORM

1. EQUIPMENT ITEM: _____

2. MANUFACTURER: _____

3. EQUIPMENT TAG NUMBER(S): _____

4. LOCATION OF EQUIPMENT: _____

5. WEIGHT OF INDIVIDUAL COMPONENTS (OVER 100 POUNDS): _____

_____

_____

_____

6. NAMEPLATE DATA:

   Horsepower: _____

   Amperage: _____

   Voltage: _____

   Service Factor (S.F.): _____

   Speed: _____

   ENC Type: _____

   Capacity: _____

   Other: _____

7. MANUFACTURER'S LOCAL REPRESENTATIVE:

   Name: _____

   Address: _____

   Telephone Number: _____

8. MAINTENANCE REQUIREMENTS:

| Maintenance Operation | Frequency | Lubricant (if applicable) | Comments |
|---|---|---|---|
| (List each operation required. Refer to specific information in manufacturer's manual, if applicable) | (List required frequency of each maintenance operation) | (Refer by symbol to lubricant list as required) | |
| | | | |
| | | | |

9. LUBRICANT LIST:

| Reference Symbol | Conoco Phillips | Exxon/Mobil | BP/Amoco | Other (List) |
|---|---|---|---|---|
| (Symbols used in Item 8 above) | (List equivalent lubricants, as distributed by each manufacturer for the specific use recommended) | | | |
| | | | | |
| | | | | |
| | | | | |

10. SPARE PARTS (recommendations): _____

_____

11. COMMENTS: _____

_____

12. GENERAL INFORMATION:

Date Accepted:* _____

Expected Life:* _____

Project Name and Number: _____

Design Engineer: _____

13. WARRANTY:

Start Date: _____

Expiration Date: _____

Prorated: _____

# SECTION 01_78_36

# WARRANTIES AND BONDS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Warranty and bonds requirements.

### 1.02 WARRANTY REQUIREMENTS

A. See General Conditions 61 and 62 for project warranty requirements.

### 1.03 BONDS

A. Not Used

## PART 2 PRODUCTS (NOT USED)

## PART 3 EXECUTION (NOT USED)

END OF SECTION

# SECTION 01_81_50

# DESIGN CRITERIA

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Design criteria for use in the selection of equipment and appurtenances specified in Technical Sections of these Specifications and indicated on the Drawings.
   2. Criteria for design of systems, components and equipment fabricated off site and shipped to the construction site for installation by others.

B. The criteria in this Section apply throughout the Work, unless additional criteria, or more restrictive criteria, are indicated.
   1. Additional criteria and requirements relevant to specific locations, specific materials, and specific equipment are indicated on the Drawings and in the Technical Sections.

### 1.02 REFERENCES

A. American Society of Civil Engineers (ASCE):
   1. 7-16 - Minimum Design Loads and Associated Criteria for Buildings and Other Structures. (ASCE 7.)
   2. Local amendments: Larimer County, Colorado.

B. International Code Council (ICC):
   1. International Energy Conservation Code (IECC).
   2. International Plumbing Code (IPC).

## PART 2 PRODUCTS

### 2.01 DESIGN CRITERIA - SITE INFORMATION

A. Site name: Source Water Pump Station.
   1. Street address:
      a. Coordinates (approximate): Latitude 40.669527; Longitude -105.088229.
   2. Site elevation (approximate):
      a. 5141.5 feet (NAVD 88).

### 2.02 DESIGN CRITERIA - REGULATORY REQUIREMENTS

A. Requirements of authorities having jurisdiction over the Project are included in Section 01_41_00 - Regulatory Requirements.

## 2.03 DESIGN CRITERIA - OPERATING ENVIRONMENT

A. Drawings and Technical Sections include additional criteria and requirements relevant to specific locations, materials, and equipment.

B. Indoor conditions:
   1. Humidity:
      a. Moisture/humidity conditions: As specified, and as defined in individual equipment sections.

## 2.04 DESIGN CRITERIA - STRUCTURAL

A. General:
   1. Criteria for structural design of:
      a. Equipment at locations subject to seismic events.

B. Delegated Design:
   1. As specified in Section 01_35_73 - Delegated Design Procedures.
   2. Structural engineering design shall be performed by a Professional Engineer licensed in the State of Colorado.

C. Structure risk category:
   1. Develop design loads and provide detailing in accordance with the provisions of ASCE 7 and the building code specified in Section 01_41_00 - Regulatory Requirements, based on the Structure Risk Category indicated in Table: Project Structures - Risk Category and Seismic Design Information.

D. Seismic loads:
   1. Seismic design parameters: Basic parameters - ASCE 7:
      a. Ground motion $MCE_R$, 5 percent damped:
         1) Short periods, Ss = 0.198 g.
         2) 1 second period, $S_1$ =0.056 g.
      b. Peak ground acceleration, $MCE_G$:
         1) Peak ground acceleration, PGA = 0.105 g.
      c. Mapped long-period transition period:
         1) TL =4 seconds.
   2. Structures - General:
      a. Seismic Design Category (SDC): As indicated in the following Table: Project Structures - Risk Category and Seismic Design Information.

**Table: Project Structures - Risk Category and Seismic Design Information**

| Area | Description | Risk Category | Site Class | $S_{DS}$ | $S_{D1}$ | Seismic Design Category(1) |
|---|---|---|---|---|---|---|
| All | All Structures | IV | C | 0.172 | 0.056 | C |

Notes:

(1) Seismic Design Category for Delegated Design, and for seismic certification of electrical and mechanical equipment as required by ASCE 7.

b. Structure response modification coefficient, R:
1) In accordance with ASCE 7 and the requirements of the Technical Sections.

3. Non-structural components - General:
a. Includes:
1) Mechanical and electrical equipment.
b. Seismic design requirements for non-structural components are based on the Seismic Design Category (SDC) of the structure or facility where the equipment is installed.
c. Design components in accordance with the requirements of ASCE 7, Table 13.2-1.
d. Component amplification factor (ap), response factor (Rp), and overstrength factor for anchorage to concrete (Ωo):
1) Mechanical and electrical components and systems: In accordance with ASCE 7, Table 13.6-1, unless otherwise indicated in the Technical Sections for these items.
e. Component importance factor, $I_p$:
1) In accordance with the following Table: Component Importance Factor for Seismic Design, $I_p$.
2) For items not listed in Table: Component Importance Factor for Seismic Design, $I_p$, designate importance factor in accordance with the provisions of ASCE 7, Chapter 13, and submit to the Engineer for review prior to developing calculations and details related to that component.

**Table: Component Importance Factor for Seismic Design, $I_p$**

| Structure Seismic Design Category | Components | $I_p$ |
|---|---|---|
| All | All equipment and components | 1.5 |

E. Operational loads:
1. Loads may include equipment vibration, torque, thermal effects, effects of internal contents (weight and sloshing), surge or “water hammer,” and other load conditions.
2. Design for loads indicated by the equipment manufacturer.
3. Design for loads indicated in the Technical Sections for equipment and appurtenances.

F. Serviceability considerations:
1. Deflection, unless otherwise indicated on the Drawings, or specified:
a. Beam deflection as fraction of span:
1) Equipment supports: L/450.

## PART 3 EXECUTION

### 3.01 GENERAL

A. Design approach and criteria in accordance with:
   1. Regulatory requirements, including, but not limited to, the building code specified in Section 01_41_00 - Regulatory Requirements.
   2. Reference standards and project-specific design criteria listed in this Section.
   3. Specific requirements for individual elements and components of the Work as specified in subsequent Technical Sections.

B. In the event of conflicts between design criteria, contact Engineer for interpretation.

### 3.02 DELEGATED DESIGN

A. Calculations:
   1. Where submittal of calculations is required:
      a. Provide complete calculations, including sketches to illustrate the design concepts being evaluated, and details to fully describe proposed construction.

B. Shop Drawings:
   1. Describing components and manufacturer's requirements for connections.

END OF SECTION

## SECTION 26_05_00

## COMMON WORK RESULTS FOR ELECTRICAL

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Requirements for electrical:
      a. Basic design and performance criteria.
      b. Prescriptive requirements for common components.

B. Contract Drawings:
   1. Schematic diagrams:
      a. Controls are shown as de-energized.
      b. Add relays, where required, to provide necessary contacts for the control system or where needed to function as interposing relays for control voltage coordination, equipment coordination, or control system voltage drop considerations.
      c. Mount devices shown on motor controller schematic diagrams in the controller compartment enclosure, unless otherwise noted.
   2. Plan drawings:
      a. Electrical drawings show desired locations, arrangements, and components of the electrical Work in a diagrammatic manner.
      b. Locations and sizes of equipment are approximate only.

### 1.02 REFERENCES

A. Abbreviations:
   1. FAT: Factory acceptance test that is also referred to as source test.
   2. ICSC: Instrumentation and controls subcontractor.
   3. PCIS: Process control and instrumentation system.

B. Standards:
   1. American National Standards Institute (ANSI).
   2. National Electrical Manufacturers Association (NEMA):
      a. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).
   3. National Fire Protection Association (NFPA):
      a. 70 - National Electrical Code (NEC).
   4. Underwriters Laboratories, Inc. (UL).

### 1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. LCP: Local control panel: Operator interface panel that may contain pilot type control devices, operator interface devices, control relays, etc., and does not contain a PLC or RIO.

2. PCM: Process control module: An enclosure containing any of the following devices: PLC, RTU, or RIO.
3. Space: Portion of a switchgear, motor control center, panelboard, switchboard, or control panel that does not physically contain a device but is capable of accepting a device with no modifications to the equipment.
    a. Furnish hardware to accommodate installation of future circuit breakers, instruments, relays, and controls.
    b. Wire relay and circuit breaker control power and network connections to the compartment and provide terminations.
    c. Space for future devices shall include:
        1) All necessary bus.
        2) Device supports and mounting equipment.
        3) Device connections to bus work.
        4) Wire troughs or raceway space.
4. Spare: Portion of a switchgear, motor control center, panelboard, switchboard, or control panel that physically contains a device with no load connections to be made.
5. Unequipped space: Portion of a switchgear, motor control center, panelboard, switchboard, or control panel that does not physically contain a device, standoff, bus, hardware, or other equipment.
6. Vendor control panel (VCP): Control panels that are furnished with particular equipment by a vendor other than the ICSC. These panels may contain PLCs, RIO, OIT, HMI, etc.

## 1.04 DELEGATED DESIGN (NOT USED)

## 1.05 SUBMITTALS (NOT USED)

## 1.06 QUALITY ASSURANCE

A. General:
    1. Furnish equipment listed by and bearing the label of UL or of an independent testing laboratory acceptable to the Engineer and the Authority Having Jurisdiction.

## 1.07 DELIVERY, STORAGE, AND HANDLING

A. Shipping precautions:
    1. After completion of shop assembly and successful factory testing, pack equipment in protective crates, and enclose in heavy duty polyethylene envelopes or secured sheeting to provide complete protection from damage, dust, and moisture.
    2. Place dehumidifiers, when required, inside the polyethylene coverings.
    3. Skid-mount the equipment for final transport.
    4. Provide lifting rings for moving without removing protective covering.
    5. Display boxed weight on shipping tags together with instructions for unloading, transporting, storing, and handling at the job site.

## 1.08 PROJECT OR SITE CONDITIONS

A. As specified in Section 01_81_50 - Design Criteria.

## 1.09 ADMINISTRATIVE REQUIREMENTS (NOT USED)

# PART 2 PRODUCTS

## 2.01 GENERAL (NOT USED)

## 2.02 DESIGN AND PERFORMANCE CRITERIA

A. Equipment mounting and anchoring:
   1. Design equipment for dead load, running loads, loads during start-up, seismic load specified in Section 01_81_50 - Design Criteria, and other loads as required for proper operation of equipment.
      a. For equipment with an operating weight of 400 pounds or greater and equipment that is supported higher than 4 feet above the floor, provide calculations for:
         1) Operating weight and location of the centroid of mass for the equipment.
         2) Forces and overturning moments.

## 2.03 MANUFACTURERS (NOT USED)

## 2.04 MATERIALS

A. Enclosures:
   1. Provide enclosures for electrical, instrumentation, and control equipment, regardless of Supplier or Subcontractor furnishing the equipment, that meet the requirements of NEMA Standard 250.
      a. Provide metallic enclosures unless specifically indicated otherwise.

B. Stainless steel:
   1. Where stainless steel is indicated or used for any portion of the electrical Work, provide a non-magnetic, corrosion-resistant alloy, ANSI Type 316, satin finish.
   2. Provide exposed screws of the same alloys.
   3. Use stainless steel hardware, when chemically compatible, in all chemical areas or areas requiring NEMA Type 4X construction.
   4. Do not use stainless steel in any area containing chlorine, gas or solution, chlorine products or ferric chloride.

C. Plant area electrical work requirements:
   1. Provide electrical materials in accordance with the following table, unless otherwise specifically indicated on the Drawings.

| Table 1. Electrical Material Requirements | | |
|---|---|---|
| **Plant Area** | **Environment:<br>W = Wet<br>D = Damp<br>C = Clean/dry<br>X = Corrosive<br>H = Hazardous** | **NEMA Enclosure Type** |
| Electrical and Control Room | C | 1 |
| Pump Room | W | 4X SST |
| Outdoor | W, X | 4X SST |

## PART 3 EXECUTION

### 3.01 EXAMINATION (NOT USED)

### 3.02 PREPARATION (NOT USED)

### 3.03 INSTALLATION (NOT USED)

### 3.04 OWNER TRAINING (NOT USED)

### 3.05 ADJUSTING (NOT USED)

### 3.06 CLEANING (NOT USED)

END OF SECTION

# SECTION 26_05_10

# MEDIUM VOLTAGE MOTORS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. 3-phase, form-wound, squirrel cage induction, medium voltage motors.

### 1.02 REFERENCES

A. American Petroleum Institute (API):
   1. 541 - Form-Wound Squirrel Cage Induction Motors - 500 Horsepower and Larger.
   2. 547 - General Purpose Form-Wound Squirrel Cage Induction Motors - 250 Horsepower and Larger.

B. Institute of Electrical and Electronics Engineers (IEEE):
   1. 85 - IEEE Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery.
   2. 112 - IEEE Test Procedures for Polyphase Induction Motors and Generators.

C. National Electrical Manufacturers Association (NEMA):
   1. MG 1 - Motors and Generators.

### 1.03 DELEGATED DESIGN (NOT USED)

### 1.04 SUBMITTALS

A. Furnish Submittals as specified in Section 01_33_00 - Submittal Procedures.

B. Product data:
   1. Descriptive bulletins for motor and accessories.
   2. Complete bill of material identifying all accessories.
   3. Machine tag and loop number as identified in the Contract Documents.
   4. Weight of complete motor and of rotating parts.
   5. Electrical data:
      a. Voltage and phase.
      b. Nameplate horsepower.
      c. Nameplate service factor.
      d. At rated horsepower and voltage:
         1) Full load amps.
         2) Revolutions per minute.
      e. Efficiency at 1/2, 3/4, and full load.
      f. Power factor at 1/2, 3/4, and full load.

g. Locked rotor withstand time, with the motor at ambient temperature and at its maximum rated operating temperature, at 70 percent, 80 percent, 90 percent, and 100 percent of rated voltage.
h. NEMA design.
i. Description of insulation system.
j. Winding insulation class and rated ambient temperature.
k. Motor data for short-circuit and coordination study:
1) Submit design values for machine characteristics, including the following:
a) Subtransient reactance ($X'_d$).
b) Transient reactance ($X'_d$).
c) Negative sequence reactance (X2).
d) Zero sequence reactance (Xo).

6. Performance curves:
a. Torque, current, and power factor vs. speed curves at 100 percent rated voltage.
b. Torque and current curves at 80 percent rated voltage.
c. Rotor and stator thermal damage curves.
d. Motor damage, safe stall time and acceleration curves at 80 percent, 90 percent and 100 percent of rated voltage.
7. Accessories data:
a. Space heaters:
1) Voltage.
2) Watts.
b. Winding and bearing temperature detectors:
1) Quantity and location.
2) Type.
3) Rating.
4) Recommended alarm and trip settings in degrees Celsius for the stator winding and bearing temperature detectors.
8. Mechanical data:
a. Bearing design and bearing life calculations.
9. Recommended spare parts list.
10. Itemized list of special tools required.

C. Shop Drawings:
1. Dimensional outline, detail, and cross-sectional drawings.
a. Show location of terminal boxes, identifying connections to be made in each.
2. Wiring diagrams for accessory devices, including RTDs, current transformers, space heaters, and vibration switches.
3. Dimensions and arrangements of terminal boxes showing terminal identification and locations, and number and size of conduit entries.

D. Certification that the selected motor meets the compatibility requirement specified in this Section.

E. Quality Control Submittals:
1. Manufacturer’s representative qualifications.

2. Manufacturer's Certificate of Source Testing as specified in Section 01_75_17 - Commissioning.
3. Test reports.

F. Owner Training Submittals:
1. As specified in Section 01_75_17 - Commissioning.

G. Operation and maintenance manuals:
1. Spare parts list with supplier names and part numbers.
2. Start-up and commissioning instructions and data.
3. Maintenance manual:
a. As specified in Section 01_78_24 - Operation and Maintenance Manuals.
b. Instructions covering details pertaining to care and maintenance of equipment as well as identifying all parts.
c. Include, at a minimum, the following:
1) As-built version of Submittal Drawings.
2) Safety procedures, equipment, and precautions.
3) Initial test, adjustment, alignment, and start-up procedures, including applicable values and tolerances.
4) Procedures for normal starting, running, and shutdown.
5) Procedures for emergency shutdown.
6) Periodic inspections and adjustments.
7) Lubrication requirements.
8) Routine maintenance and repairs.
9) Special tools and recommended spare parts.
10) Test reports.

## 1.05 QUALITY ASSURANCE

A. Certify that the motor, when installed and driven by the actual variable frequency drive furnished:
1. Is capable of satisfactory performance under specified conditions with the actual pumps furnished.
2. Meets the requirements of the latest edition of NEMA MG 1, Part 31.
3. Is matched to the actual variable frequency drive being furnished.
4. Will not experience premature bearing failure due to induced voltages or currents caused by the high frequency output of the drive.

## 1.06 DELIVERY, STORAGE, AND HANDLING (NOT USED)

## 1.07 PROJECT OR SITE CONDITIONS

A. Environmental requirements:
1. Motor(s) shall be de-rated in accordance with the manufacturer's guidelines for the Project altitude and ambient temperature as specified in Section 01_81_50 - Design Criteria.

## 1.08 ADMINISTRATIVE REQUIREMENTS (NOT USED)

## 1.09 WARRANTY

A. As specified in Section 01_78_36 - Warranties and Bonds.

## 1.10 SYSTEM START-UP (NOT USED)

## 1.11 MAINTENANCE

A. Furnish the following spare parts:
   1. 1 complete set of air filters for each motor.

# PART 2 PRODUCTS

## 2.01 GENERAL (NOT USED)

## 2.02 DESIGN AND PERFORMANCE CRITERIA

A. Provide equipment and components that are fully rated for the Site elevation and operating environment where the equipment will be installed as specified in Section 01_81_50 - Design Criteria and as indicated on the Drawings.

B. Motors shall be furnished by the equipment manufacturer as specified in the equipment specification section.

C. Coordinate characteristics and requirements of driven equipment, reduced voltage solid state starters, variable frequency drives, and accessories, to ensure a complete, fully functional, coordinated installation.

## 2.03 MANUFACTURERS

A. One of the following or equal:
   1. General Electric.
   2. National Oilwell Varco.
   3. Teco Westinghouse.
   4. Toshiba.

## 2.04 MATERIALS (NOT USED)

## 2.05 MANUFACTURED UNITS (NOT USED)

## 2.06 EQUIPMENT

A. General:
   1. 3-phase induction motors.
   2. Voltage: 4,000 volts, designed to operate on system with nominal 4,160 volts.
   3. Motors driving identical machines shall be identical.
   4. Motors shall be inverter duty rated:
      a. Compatible with the variable frequency drives furnished.
      b. Inverter duty rated and labeled.
      c. In accordance with NEMA MG 1, Part 31.
      d. Winding insulation in accordance with NEMA MG 1, Part 31.40.4.2.

e. Capable of running continuously at minimum pump speed, with no harmful effects or overheating.
f. Provide shaft grounding brushes to prevent bearing damage from induced shaft voltage.
g. Provide additional features as required to prevent premature failure of any motor component due to operation with the variable frequency drives being furnished.

5. Efficiency and power factor:
   a. The guaranteed motor efficiency at rated voltage and frequency shall not be less than 95.2 percent at full load, 95.0 percent at 3/4 load, and 94.8 percent at 1/2 load.
   b. The guaranteed power factor at rated voltage and frequency shall not be less than 84 percent at full load, 80 percent at 3/4 load, and 72 percent at 1/2 load.
   c. Coordinate power factor correction capacitors requirement with starter supplier. Minimum corrected full-load power factor is 95 percent.
   d. Determine efficiencies in accordance with IEEE 112, Method F.
6. Horsepower as indicated on the Drawings and equipment schedules:
   a. Horsepower ratings indicated on the Drawings are based on vendor's estimates. Provide motors sized for the load of the actual equipment furnished without operating in the service factor:
      1) If the size of the motor required to drive the actual equipment furnished is larger than the size indicated on the Drawings, make structural, mechanical, and electrical changes that are necessitated by the increase, including, but not limited to:
         a) Motor starter or VFD rating.
         b) Electrical distribution equipment size and ratings.
         c) Electrical service and transformer sizes.
         d) Conductor and conduit sizes for service, feeder, and motor branch circuit.
7. Service factor:
   a. 1.0 when operating on a variable frequency drive.
8. Torque:
   a. Provide motors that develop sufficient torque to accelerate the actual load to full speed at voltage 10 percent less than motor nameplate rating.
   b. When started using reduced voltage starters:
      1) Provide motors that develop sufficient torque to accelerate the actual load to full speed at the starting ramp and current limit of the starter.
9. Enclosures:
   a. As specified in the individual equipment specifications.
   b. Provide with filters for inlet air passages:
      1) Filters must remove 90 percent of particulates 10 microns and larger.
      2) Easily replaceable while motor is operating.
10. Hardware:
    a. Type 316 stainless steel.
11. Conduit boxes:
    a. Cast iron or stamped steel.
    b. Provide gaskets at the following interfaces:
       1) Frames and conduit boxes.

2) Conduit boxes and box covers.
3) Size as required to accommodate conductor and conduit quantities and sizes indicated on the Drawings and specified in the conduit schedule.

c. Main power conduit box:
1) Provide NEMA 2-hole pads mounted on standoff insulators for terminating medium-voltage power cables.
2) Provide space for medium-voltage terminations, including stress cones, and adequate space to allow connections without bending incoming cables beyond the cable manufacturer's minimum bending radius recommendations.
3) Suitable for bottom conduit entry as indicated on the Drawings.
4) Provide a grounding bus inside the conduit box for motor frame grounding.

d. Accessory terminal boxes:
1) Provide a separate box for motor winding heater connections.
2) Provide a separate conduit box for RTD connections.
3) Provide a separate conduit box with short-circuiting terminal blocks for current transformer connections:
a) Current transformer terminals may be located in the main power conduit box provided that suitable barriers are installed to isolate the terminals from medium-voltage connections, the conduit entry for CT leads into the isolated terminal section, and that the terminals are accessible without removing the main power conduit box cover.

12. Motor bearings:
a. Provide bearings (deep groove ball bearings or oil-bathed sleeve bearings suitable for the load), to ensure vibration minimization specific to load rpm and torques (axial and off axis) which are encountered.
b. Antifriction.
c. Bearings and lubrication suitable for ambient temperature and temperature rise.
d. Suitable for intended application and have ABMA L-10 rating life of 60,000 hours or more.
e. Provide water cooling if required to meet the L-10 life rating:
1) Using pump discharge water.
2) Coordinate pressure and flow rate requirements with the pump manufacturer.
3) Coordinate inlet and outlet connection details and requirements with the pump manufacturer.
4) Use stainless steel for water pipes and coding coils.
f. Fit bearings with easily accessible lubrication fittings.
g. Provide sight glasses for oil reservoirs (where oiled sleeve-type bearings are used).
h. For vertical motors or vertical shaft loads, provide thrust bearings suitable for the weight of the rotor and pump plus maximum down thrust delivered by the pump, and for any up thrust that can be delivered by the pump or driven load.
i. Insulate bearings.

B. Stator:
   1. Core:
      a. Built up from high grade, non-aging laminated silicon steel.
      b. Insulate each lamination to minimize eddy current losses.
   2. Windings:
      a. Form-wound copper coils.
      b. Coils of the same size and shape.
      c. Strand insulation: Polyester glass fiber or equal high temperature insulating film.
      d. Turn-to-turn insulation:
         1) Designed to prevent insulation damage from voltage surges.
         2) For variable frequency drive applications, design for surges as identified in NEMA MG 1, Part 31, paragraph 31.40.4.2.
      e. Coil insulation: Suitable for voltage class of the motor, tightly applied to prevent voids.
      f. Insulation class: F.
      g. Design temperature rise consistent with Class B insulation when delivering full motor service factor at an ambient temperature of 40 degrees Celsius.
      h. Crimp and silver solder coil and lead connections.
      i. Fully insulate and brace end turns, including coil and lead connections. Provide surge ring and bracing suitable for maximum fault current as determined by the short-circuit and coordination study.
   3. Entire stator vacuum pressure impregnated with non-hygroscopic polyester or epoxy resin, and heat cured.
   4. Motor leads:
      a. Insulated leads with non-wicking, non-hydroscopic material. Class F insulation.
   5. Noise:
      a. Maximum operating noise level of 85 dB measured in accordance with IEEE 85.

C. Rotor:
   1. Shaft:
      a. Constructed of forged or rolled steel, machined and finished.
      b. Sufficient strength to withstand stresses resulting from normal operation at any speed up to 125 percent of synchronous speed.
      c. Connections to match driven equipment.
   2. Core:
      a. Built up from high grade, non-aging laminated silicon steel.
      b. Insulate each lamination to minimize eddy current losses.
   3. Bars:
      a. Copper or copper alloy.
      b. Size and shape as required to provide starting and running characteristics compatible with the driven load and starting method.
      c. Secured to the rotor slots to minimize movement or vibration.
      d. Attach bars to end rings by induction or torch brazing.
   4. Statically and dynamically balance rotor before assembly into the motor.
   5. Provide anti-reverse ratchet.

## 2.07 COMPONENTS (NOT USED)

## 2.08 ACCESSORIES

A. Space heaters:
   1. Provide belted or cartridge space heaters mounted within the motor enclosure sized to heat the motor winding to approximately 5 degrees Celsius above ambient temperature.
   2. Rating: 120 volts, single-phase, unless otherwise specified.
   3. Power leads for heaters wired into a separate conduit box.
   4. Installed within motor enclosure adjacent to core iron.

B. Nameplates:
   1. Provide motors with a permanent, stainless steel nameplate indelibly stamped or engraved with:
      a. NEMA standard motor data.
      b. Bearing description and lubrication instructions.

C. Winding temperature detectors:
   1. Provide factory installed winding temperature detector with leads terminating in a separate conduit box:
      a. RTD type, 2 per phase.
      b. Platinum, 100 ohms nominal at 0 degrees Celsius.
      c. Temperature coefficient of resistance compatible with monitoring equipment.

D. Bearing temperature detectors:
   1. Where specified by the driven equipment specification or as indicated on the Drawings.
   2. RTD type, ratings, and wiring matching the winding RTDs.

E. Vibration detectors:
   1. Where specified in the driven equipment specification.
   2. Vibration switches:
      a. Furnish 2 switches, 1 installed to respond to vibration along the X axis, the other to vibration along the Y axis.
      b. Transducers:
         1) Remote-mounted accelerometer in outdoor weather-protected housing.
         2) Same manufacturer as vibration switch.
         3) Securely threaded directly into motor frame near the top of the motor.
         4) Connect each transmitter to its switch with moisture-resistant cable with stainless steel armor and jacket, as recommended by the transducer manufacturer. Length as required to connect transducer to remote-mounted switch.
      c. Switch:
         1) Convert accelerometer input to vibration velocity.
         2) Power supply: 120 VAC.
         3) 20-second time delay on motor start, as determined from motor running input.
         4) 2 form C output relays:
            a) Each rated for 120 VAC, 5 amps.
            b) Manual reset.

c) 1 shutdown contact adjustable from 0.1 to 1.5 inches per second.
d) 1 alarm contact adjustable from 10 to 90 percent of the shutdown setting.
e) Time delay for each output, independently adjustable from 2 to 15 seconds.

d. Metrix 440 series with SA6200A accelerometer in 7295 housing and 9334-111 armored cable or approved equal.

F. Air filter differential pressure switch:
1. Furnish differential pressure switch for motors to indicate when filters require cleaning or replacement:
a. Form C contact rated for 5 amps at 120 VAC or 24 VDC.

G. Current transformers:
1. Furnish current transformers as specified in Section 26_09_13 - Electrical Power Monitoring in the main power conduit box for motor differential protection.
2. Connect to short-circuiting terminal blocks in the current transformer accessory conduit box.
3. 3 current transformers, 1 per each phase.
4. Core balance or full differential as required for compatibility with motor protection relay furnished.
5. Ratio and accuracy class as determined by the short-circuit and coordination study, and for the actual connections (core balance or full differential).

## 2.09 SOURCE QUALITY CONTROL

A. Source Testing:
1. Factory tests:
a. Submit test procedure a minimum of 6 weeks before factory tests.
b. Perform tests on motors in accordance with API 541 and IEEE 112. Perform tests required by these standards for motors and the following tests as described in API 541:
1) Surge comparison test.
2) Component balance.
3) Bearing dimensional and alignment checks.
4) DC high-potential test to establish reference values for field tests.
5) Air filter differential pressure test.
2. Test one or more motors with complete equipment system as required by the driven equipment specification section.
3. Provide final machine characteristic data determined from the tests.
4. Furnish test reports and the Manufacturer’s Certificate of Source Testing.

# PART 3 EXECUTION

## 3.01 EXAMINATION (NOT USED)

## 3.02 PREPARATION (NOT USED)

## 3.03 INSTALLATION (NOT USED)

## 3.04 FIELD QUALITY CONTROL (NOT USED)

## 3.05 OWNER TRAINING

A. Perform Owner Training as specified in Section 01_75_17 - Commissioning.

END OF SECTION

# SECTION 26_05_53

# IDENTIFICATION FOR ELECTRICAL SYSTEMS

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Identification of electrical equipment, devices and components.
   2. Material, manufacturing and installation requirements for identification devices.

### 1.02 REFERENCES

A. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).

B. National Fire Protection Association (NFPA):
   1. 70 - National Electrical Code (NEC).

C. Occupational Safety and Health Administration (OSHA).

### 1.03 DELEGATED DESIGN (NOT USED)

### 1.04 SUBMITTALS

A. Furnish Submittals as specified in Section 01_33_00 - Submittal Procedures.

B. Product data:
   1. Nameplates:
      a. Color.
      b. Size:
         1) Outside dimensions.
         2) Lettering.
      c. Material.
      d. Mounting means.

### 1.05 QUALITY ASSURANCE (NOT USED)

### 1.06 DELIVERY, STORAGE, AND HANDLING (NOT USED)

### 1.07 PROJECT OR SITE CONDITIONS

A. As specified in Section 01_81_50 - Design Criteria.

### 1.08 ADMINISTRATIVE REQUIREMENTS (NOT USED)

### 1.09 WARRANTY

A. As specified in Section 01_78_36 - Warranties and Bonds.

## PART 2 PRODUCTS

### 2.01 GENERAL

A. Nameplates:
   1. Provide for control panel operator devices (e.g., pushbuttons, selector switches, pilot lights, etc.):
      a. Same material and same color and appearance as the device nameplates to achieve an aesthetically consistent and coordinated system.

### 2.02 DESIGN AND PERFORMANCE CRITERIA

A. Nameplates:
   1. Provide for each piece of electrical equipment, device, control panel, and control panel components.
   2. Identical style, color, and material throughout the facility.
   3. Device nameplates information:
      a. Equipment tag number as indicated on the Drawings.

B. Wire numbers:
   1. Vendor to coordinate the wire numbering system with the installing contractor so that every field wire has a unique number associated with it for the entire system:
      a. Correspond to the terminal block number to which they are attached in the control panel.
      b. Internal panel wires on a common terminal shall have the same wire number.

### 2.03 MANUFACTURERS

A. Nameplates and signs:
   1. One of the following or equal:
      a. Brady.
      b. Seton.

### 2.04 MATERIALS

A. Nameplates:
   1. Colors:
      a. Warning: White-center, red face.
      b. Other: Black-center, white face.
   2. Laminated plastic engraving stock:
      a. 3/32-inch thick material.
      b. 2-ply.
   3. With chamfered edges.
   4. Lettering:
      a. Block style engraved characters of adequate size to be read easily from a distance of 6 feet.
      b. Minimum letter height: 1/8 inch.

B. Signs:
   1. Automatic equipment and high voltage signs:
      a. Suitable for exterior use.
      b. In accordance with OSHA regulations.

## PART 3 EXECUTION

### 3.01 EXAMINATION (NOT USED)

### 3.02 PREPARATION (NOT USED)

### 3.03 INSTALLATION

A. Nameplates:
   1. Attach to equipment with rivets, bolts, or sheet metal screws, approved waterproof epoxy-based cement or install in metal holders welded to the equipment.
   2. Provide for each disconnecting means with the following:
      a. Equipment served, voltage, and fuse size as required.
      b. Identification of the circuit source that supplies the disconnecting means.
   3. On NEMA Type 4, NEMA Type 4X, or NEMA Type 7 enclosures, use epoxy-based cement to attach nameplates.
   4. Aligned and level or plumb to within 1/64 inch over the entire length:
      a. Misaligned or crooked nameplates shall be remounted or provide new enclosures at the discretion of the Engineer.

B. Signs and labeling:
   1. Furnish and install permanent warning signs at mechanical equipment that may be started automatically or from remote locations:
      a. Fasten warning signs with round head stainless steel screws or bolts.
      b. Locate and mount in a manner to be clearly legible to operations personnel.
   2. Furnish and install permanent and conspicuous warning signs on equipment (front and back), doorways to equipment rooms, pull boxes, manholes, etc., where the voltage exceeds 600 volts.
   3. Furnish and install warning signs on equipment that has more than one source of power.
      a. Warning signs to identify every panel and circuit number of the disconnecting means of external power sources.
   4. Place warning signs on equipment that has 120 VAC control voltage source used for interlocking.
      a. Identify panel and circuit number or conductor tag for control voltage source disconnecting means.
   5. Label service entrance equipment, switchgear, switchboards, MCCs, panelboards, and transfer switches with the available short circuit current, equipment label, and date of application in accordance with NEC. Coordinate with Section 26_05_74 - Electrical System Studies for available fault current data.

## 3.04 FIELD QUALITY CONTROL (NOT USED)

END OF SECTION

## SECTION 26_05_74

## ELECTRICAL SYSTEM STUDIES

### PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Short-circuit fault analysis studies.

### 1.02 REFERENCES

A. American National Standards Institute (ANSI).

B. National Fire Protection Association (NFPA):
   1. 70E - Standard for Electrical Safety in the Workplace.

### 1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Initial short-circuit fault analysis: An analysis done based on the Drawings and utility information. The purpose is to identify the available fault current at each piece of equipment to make sure it is properly rated.

### 1.04 DELEGATED DESIGN

A. Signed and sealed electrical system study reports.

### 1.05 SUBMITTALS

A. Furnish Submittals as specified in Section 01_33_00 - Submittal Procedures.

B. Credentials of the individual(s) performing the study and the individual in responsible charge of the study.

C. General:
   1. Format and quantity:
      a. A complete set of electronic files, including the electrical system model(s), configuration files, custom libraries, and any other files used to perform the studies and produce the reports, in PDF format.
   2. One-line diagrams:
      a. The following information shall be included at a minimum:
         1) Motor horsepower.
         2) Transformer data:
            a) kVA.
            b) Configuration.
         3) Cable data:
            a) Insulation.

b) Size.
c) Length.

b. Fully legible at 11-inch by 17-inch size.

D. Sharing of short-circuit fault analysis between vendors for electrical equipment.
1. The City of Thornton is bidding 2 packages of electrical equipment that will both be installed by a future contractor for a pump station. The vendors that are supplying equipment for both packages shall coordinate and share information so that studies are consistent. The City of Thornton will share contact information of the vendors for each package. Each vendor is responsible to coordinate with the other on sharing and coordinating information.

E. Initial short-circuit fault analysis:
1. Based on the Contract Documents and electric utility information.
2. Include a description of all operating scenarios.
3. One-line diagrams.
4. Indicate the estimated available short-circuit current at the line side terminals of each piece of equipment covered by the scope of the study.
a. Measure conductor lengths from the Drawings. Use of arbitrary short conductor lengths is not allowed.
b. Provide a list of assumptions used in the initial study.

## 1.06 QUALITY ASSURANCE

A. Qualifications of the entity responsible for electrical system studies:
1. Short-circuit fault analysis shall be performed with the aid of a digital computer program:
a. Point-to-point calculations are not acceptable.

## 1.07 DELIVERY, STORAGE, AND HANDLING (NOT USED)

## 1.08 PROJECT OR SITE CONDITIONS (NOT USED)

## 1.09 ADMINISTRATIVE REQUIREMENTS

A. Coordination:
1. Include the electric utility information on the minimum and maximum available fault current, minimum and maximum utility impedances, utility protective device settings, including manufacturer and model number, interrupting ratings, X/R ratios, and model information one level above the point of connection:
a. Utility tolerances and voltage variations.
b. Coordinate with the utility for changes to their protective devices and settings to achieve a coordinated system between the utility and the Owner.
2. Obtain equipment layouts and configurations from the manufacturer’s final Submittal requirements as required.

B. Use medium-voltage cable reactance based on typical dimensions of shielded cables with 133 percent insulation levels, unless otherwise indicated.

C. Meetings:
    1. Electrical system study meetings:
        a. As specified in Section 01_31_19 - Project Meetings.
        b. The individual conducting the electrical system studies leads the meeting.
        c. Meet with the Owner and Engineer 1 time.
        d. First meeting:
            1) Discuss the scope of the studies.
            2) Confirm electrical system operating modes.
            3) Confirm assumptions to be used in the electrical system study with the Owner, including, but not limited to:
                a) Maximum protective device fault clearing time.
            4) Discuss the Owner's operational requirements for both normal operation and maintenance.

D. Sequencing:
    1. Below is an outline of the typical work sequence. Proposed changes to the work sequence may be reviewed and approved by the Engineer.
        a. First system study meeting.
        b. Submit the initial short-circuit fault analysis study before submittal of any electrical equipment.
            1) Only the initial short-circuit results will be reviewed.

## PART 2 PRODUCTS

### 2.01 GENERAL (NOT USED)

### 2.02 DESIGN AND PERFORMANCE CRITERIA

A. General study requirements:
    1. Scope:
        a. Short-circuit fault analysis shall include all equipment in the power distribution system, including, but not limited to:
            1) Utility equipment (utility transformer and primary protective device).
            2) Available utility fault contribution current.
            3) All electrical equipment, including:
                a) Dry-type transformers.
                b) 240- and 208-volt panelboards.
            4) Motors.
        b. Study scenarios:
            1) Include all possible electrical system configurations, for example:
                a) Operation on normal (utility) source.
    2. Motors:
        a. Each motor shall be individually modeled:
            1) Grouping of motors for fault contribution current is not acceptable.
        b. Motors with variable frequency drives (VFDs) may be assumed to have no contribution to fault current.
    3. Use the equipment, bus, and device designations as indicated on the Drawings for all studies.

B. Short-circuit fault analysis study additional requirements:
   1. Calculate 3-phase bolted fault, line-to-line fault, line-to-ground fault, double line-to-ground fault, short-circuit 1/2 cycle momentary symmetrical and asymmetrical RMS, 1-1/2 to 4 cycle interrupting symmetrical RMS, and 30-cycle steady-state short-circuit current values at each piece of equipment in the distribution system.
   2. Evaluate bus bracing, short-circuit ratings, fuse interrupting capacity and circuit-breaker-adjusted interrupting capacities against the fault currents, and calculate X/R values:
      a. Identify and document all devices and equipment as either inadequate or acceptable.
   3. Calculate line-to-ground and double line-to-ground momentary short-circuit values at buses having ground-fault devices.
   4. Provide calculation methods, assumptions, one-line diagrams, and source impedance data, including utility X/R ratios, typical values, recommendations, and areas of concern.

## 2.03 MANUFACTURERS

A. Electrical system study software: One of the following or equal:
   1. Operation Technology, Inc., ETAP.
   2. SKM Systems Analysis, Powertools.

## 2.04 EXISTING PRODUCTS (NOT USED)

## 2.05 MATERIALS (NOT USED)

## 2.06 MANUFACTURED UNITS (NOT USED)

## 2.07 EQUIPMENT (NOT USED)

## 2.08 COMPONENTS (NOT USED)

# PART 3 EXECUTION

## 3.01 EXAMINATION (NOT USED)

## 3.02 PREPARATION (NOT USED)

## 3.03 INSTALLATION (NOT USED)

## 3.04 OWNER TRAINING (NOT USED)

## 3.05 FIELD QUALITY CONTROL (NOT USED)

## 3.06 ADJUSTING (NOT USED)

END OF SECTION

# SECTION 26_09_13

# ELECTRICAL POWER MONITORING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Power meter accessories.

### 1.02 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):
   1. C57.13.6 - Standard for High Accuracy Instrument Transformers.

### 1.03 TERMINOLOGY (NOT USED)

### 1.04 DELEGATED DESIGN (NOT USED)

### 1.05 SUBMITTALS

A. Furnish Submittals as specified in Section 01_33_00 - Submittal Procedures.

B. Product data:
   1. Accessory data:
      a. Test switch dimensions and wiring diagrams.

### 1.06 QUALITY ASSURANCE (NOT USED)

### 1.07 DELIVERY, STORAGE, AND HANDLING (NOT USED)

### 1.08 PROJECT OR SITE CONDITIONS

A. As specified in Section 01_81_50 - Design Criteria.

### 1.09 ADMINISTRATIVE REQUIREMENTS (NOT USED)

### 1.10 WARRANTY

A. As specified in Section 01_78_36 - Warranties and Bonds.

## PART 2 PRODUCTS

### 2.01 GENERAL (NOT USED)

### 2.02 DESIGN AND PERFORMANCE CRITERIA (NOT USED)

## 2.03 MANUFACTURERS (NOT USED)

## 2.04 MATERIALS (NOT USED)

## 2.05 MANUFACTURED UNITS (NOT USED)

## 2.06 EQUIPMENT (NOT USED)

## 2.07 COMPONENTS (NOT USED)

## 2.08 ACCESSORIES

A. Current transformers:
   1. Ring type:
      a. Suitable for service within low or medium voltage equipment as indicated on the Drawings.
      b. Designed to have a mechanical and thermal rating to withstand short-circuit current, stresses, and heating effects equal to the rating of the equipment of the application.
   2. Current ratio: As indicated on the Drawings.
   3. Rated in accordance with IEEE C57.13.6 with accuracy of the current transformers suitable for relay accuracy class and rated for 200 percent burden for the required connected devices.
   4. Identify polarity with standard marking or symbols.
   5. Capable of carrying rated primary current continuously without damage.
   6. Install secondary wiring from current transformers in a suitable wiring trough, or conduit to proper short-circuiting type terminal blocks for connection to relays, instruments, and other devices.
   7. 3 CTs for 3-wire systems. 4CTs for 4-wire systems.

# PART 3 EXECUTION

## 3.01 EXAMINATION (NOT USED)

## 3.02 PREPARATION (NOT USED)

## 3.03 INSTALLATION

A. Install power meter accessories in accordance with the manufacturer’s instructions in the electrical equipment as indicated on the Drawings.

## 3.04 FIELD QUALITY CONTROL (NOT USED)

## 3.05 OWNER TRAINING (NOT USED)

END OF SECTION

## SECTION 26_13_05

## PROTECTIVE RELAYS

# PART 1 GENERAL

## 1.01 SUMMARY

A. Section includes:
   1. Protective relays.
   2. Current transformers.
   3. Voltage transformers.

## 1.02 REFERENCES

A. Abbreviations:
   1. CPT: Control power transformer.
   2. CT: Current transformers.
   3. FPS: Feeder protection system.
   4. GPS: Generator protection system.
   5. PF (pf): Power factor.
   6. PU (pu): Per unit.
   7. VT: Voltage transformers.

B. Standards:
   1. Institute of Electrical and Electronics Engineers (IEEE):
      a. 1588 - IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.
      b. 1613 - IEEE Standard Environmental and Testing Requirements for Communications Networking Devices in Electric Power.
      c. C37.90.1 - IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus.
      d. C37.90.2 - IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers.
      e. C37.118 - IEEE Standard for Synchrophasor for Power Systems.
      f. C57.13 - IEEE Standard Requirements for Instrument Transformers.
   2. International Electrotechnical Commission (IEC):
      a. 60068 - Environmental testing.
      b. 60255 - Measuring relays and protection equipment.
      c. 60870 - Telecontrol equipment and systems.
      d. 61131 - Programmable controllers.
      e. 61850 - Communication networks and systems for power utility automation.
   3. Underwriters Laboratories, Inc. (UL).

## 1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. HMI: Human machine interface is a software application that presents information to an operator or user about the state of a process, and to accept and implement the operators control instructions. Typically, information is displayed in a graphical format.
   2. LOI: Local operator interface is an operator interface device consisting of an alphanumeric or graphic display with operator input functionality. The LOI is typically a flat panel type of display mounted on the front of an enclosure with either a touch screen or tactile button interface, or a display on the face of the protective relay.

## 1.04 DELEGATED DESIGN (NOT USED)

## 1.05 SUBMITTALS

A. Furnish Submittals as specified in Section 01_33_00 - Submittal Procedures.

B. Product data:
   1. Manufacturer of relay.
   2. Descriptive literature.
   3. Relay ANSI device functions.
   4. Power requirements and connections.
   5. Communications provisions and connections.
   6. Controls.
   7. Mounting.
   8. Nameplate schedule.
   9. Itemized bill of material, including manufacturer, complete model number, and options included.
   10. Description of operation.
   11. Cut sheets for components, electrical devices, and mechanical devices:
      a. Catalog information.
      b. Descriptive literature.
      c. External power and signal connections.
   12. List of recommended spare parts.
   13. Name, address, telephone number, and cell phone number of relay manufacturer’s authorized local field service technician.

C. Shop Drawings:
   1. Provide complete terminal block connection diagrams for the protective relays.
   2. Manufacturer’s recommended wiring and interconnection diagrams for the specific project to be used to compare with the electrical equipment manufacturer’s detailed Submittal.

D. Calculations:
   1. Direct current power and current requirements needed to operate the protective relays and associated equipment.

2. Current transformer sizing calculations to substantiate that the current transformers will not saturate under a maximum fault current event.
3. Burden, cable sizing, CT class, for differential CTs located remote from the switchgear or relay.

E. Resumes:
1. Provide the following resumes for review and acceptance by the Engineer:
   a. Protective relay manufacturer qualifications: A minimum of 15 years of documented experience in the Work of this Section.
   b. Documented list of a minimum of 15 electric utilities using the protective relays used on the project along with complete contact information.
   c. Protective relay programmer:
      1) Must have a minimum of 5 years' experience in programming, setting, and testing of protective relays used on the project.
      2) Certified by the protective relay manufacturer:
         a) Employee of the protective relay manufacturer.
         b) Employee of the switchgear manufacturer.
         c) Employee of the testing firm as specified in Section 26_08_50 - Field Electrical Acceptance Tests.
   d. Must fully document and substantiate experience with programming and setting the actual protective relays provided for this Project.

F. Owner Training Submittals:
1. As specified in Section 01_75_17 - Commissioning.

G. Operation and maintenance manuals:
1. Submit operating and installation instructions and a maintenance manual presenting full details for care and maintenance of equipment of every nature furnished and/or installed under this Contract.
2. Maintenance manual:
   a. Furnish with instructions covering details pertaining to care and maintenance of the equipment as well as data identifying the parts.
   b. Shall include, but are not limited to, the following:
      1) Adjustment and test instructions covering the steps involved in the initial test, adjustment, and start-up procedures.
      2) Detailed control instructions that outline the purpose and operation of every control device used in normal operation.

H. Test reports:
1. Provide .csv file, or similar format, for Engineer review of relay settings and programming.
2. Information such as 1-line diagrams, time-current curves, calculations, etc., used to determine the settings shall be submitted with the exported relay file for review.

## 1.06 QUALITY ASSURANCE

A. Relays, instrument transformers, and associated equipment shall be UL listed and labeled.

B. Specific protective relay manufacturer requirements:
   1. Minimum of 15 years documented experience in providing electric utility grade protective relays to electrical utilities.
   2. Protective relay programmer, must have a minimum of 5 years' experience in programming, setting, and testing of protective relays used on the project.

## 1.07 DELIVERY, STORAGE, AND HANDLING (NOT USED)

## 1.08 PROJECT OR SITE CONDITIONS

A. As specified in Section 01_81_50 - Design Criteria.

## 1.09 ADMINISTRATIVE REQUIREMENTS (NOT USED)

## 1.10 WARRANTY

A. As specified in Section 01_78_36 - Warranties and Bonds.

# PART 2 PRODUCTS

## 2.01 GENERAL

A. Protective relays, current transformers, and voltage transformers with the protective functions as indicated on the Drawings.

## 2.02 DESIGN AND PERFORMANCE CRITERIA

A. Specifications and Drawings show the desired functionality:
   1. It is understood that the named manufacturers' protective relays do not have the same functionality on a device-by-device comparison.
   2. It is the protective relay manufacturer's responsibility to configure the system with their products in order to provide the functionality as indicated on the Drawings and specified in this Section, using their standard products.

## 2.03 MANUFACTURERS

A. Refer to the individual relay specifications for additional listings of acceptable manufacturers and model numbers.

## 2.04 MATERIALS (NOT USED)

## 2.05 MANUFACTURED UNITS (NOT USED)

## 2.06 EQUIPMENT (NOT USED)

## 2.07 COMPONENTS

A. Protective relays:
   1. General:
      a. Furnish relays complete with devices and associated circuitry necessary to perform the required functions as specified or indicated on the Drawings.

b. Manufacturers of relays and controls are listed to describe system operating requirements.
c. Furnish material not specifically listed or shown but necessary to perform required functions.
d. Mounting:
    1) As indicated on the Drawings.
e. Provide nameplates as specified in Section 26_05_53 - Identification for Electrical Systems.

2. Lockout relay:
    a. Where indicated on the Drawings, provide an ANSI function 86 lockout relay.
    b. Operating voltage: 125 VDC.
    c. Functions:
        1) Trip control.
        2) Block close control.
        3) Green LED for ready indication.
        4) Red LED for tripped indication.
        5) Black RESET target.
        6) Orange TRIP target.
        7) Manual reset.
    d. Manufacturers: One of the following or equal:
        1) Electroswitch, Series 24.
        2) General Electric, Type SB.
3. Solid state digital relays:
    a. General:
        1) Multifunction, microprocessor based with monitoring and communications capabilities, with native IEC 61850 support.
        2) Continuous self-diagnostics.
        3) Fault recording:
            a) Monitor and record fault data.
            b) Fault events stored in event reports.
            c) Event reports saved to non-volatile memory.
        4) Front keypad and display for programming and configuration:
            a) 1 control pushbutton programmed to set relay protective functions to the minimum values.
            b) Password protection for security.
        5) A minimum of 2 programmable digital inputs and 4 Form C programmable outputs.
        6) Installation and control connections, one of the following:
            a) Draw-out case that allows removal of the relay without having to disconnect wiring. CT circuits shall be self-shorting with make before-break operation on removal of the relay.
            b) Connectorized terminals with shorting for each current input.
        7) Selection for coordination with common IEC, WH-CO, and GE-IAC curves as specified in Section 26_05_74 - Electrical System Studies. For each individual protective relay:
            a) Definite time.
            b) Moderately inverse.
            c) Inverse.
            d) Very inverse.
            e) Extremely inverse.

8) Power supply:125 VDC.
9) Provide common communications media for protective relays as follows, or as indicated on the Drawings:
    a) Copper Ethernet.
10) Provide common communications protocols for protective relays as follows, or as indicated on the Drawings:
    a) Modbus TCP.

4. Feeder protection system (FPS):
    a. Description:
        1) Provide protective, metering, and control functionality, with setup, control, and monitoring programmable logic, front panel LOI, and remote communications.
    b. Specific requirements:
        1) Directional inverse time overcurrent elements monitoring current on all 3 phases, 2 sets of neutral current calculated by the relay from phase current summation or an independent ground CT and calculated negative sequence current:
            a) Each element may be set as forward, reverse, or non-directional.
            b) User shall have the option of phase element being voltage controlled, voltage restrained, or neither (e.g., normal voltage independent overcurrent relays).
            c) Functions: 51P,51N,51G,51Q or 46.
        2) 2 sets of directional instantaneous time overcurrent elements with a user-settable time delay monitoring all 3 phases, the neutral calculated by the relay from phase current summation, the independent ground CT, and the calculated negative sequence current:
            a) Each element may be set as forward, reverse, or non-directional.
            b) Functions: 50P,50N,50G,50Q or 46 Instantaneous.
            c) Targeting shall show 67 if element is set as forward or reverse.
        3) Selection for coordination with common protective device coordination curves:
            a) As specified in Section 26_05_74 - Electrical System Studies.
            b) User-selectable reset rate to either integrating reset, to mimic the slow return to zero of induction disks, or instantaneous reset.
        4) Suitable for monitoring either 3-wire or 4-wire PT configurations:
            a) Monitor phase overvoltage, phase undervoltage, and calculate and monitor negative sequence (V2) voltage.
            b) User-settable phase overvoltage element to trip only for 1, 2, or 3 phases out of range.
            c) User-settable fixed time delay tripping for each element.
            d) User-settable phase element monitoring for either phase-phase or phase-ground.
            e) Maximum phase setting shall be 300 VPP.
            f) Function: 27,59,47N or 59Q.
        5) Monitor line currents and voltages and provide the following information:
            a) Present values: Phase, neutral and negative sequence currents, volts; forward and reverse watts, VARs, watt-hours, VAR-hours.
            b) Demand values: Phase, neutral, and negative sequence current, 3-phase watts and VARs, and peak since last demand reset.

6) User-definable programmable logic:
    a) Logic able to inter-tie relay control inputs, output contacts, LOI and HMI addressable switches, protective element logical I/O, reclosing element I/O, timer element I/O, settings group control, and relay internal alarms.
7) 4 independent setting groups selectable by user logic:
    a) Logic may utilize relay hardwire inputs, LOI or remote communications commands, relay internal logic, reclose status, or an automatic dynamic selection based on recent load levels.
8) Self-testing and alarming:
    a) Capable of monitoring breaker systems, including the trip circuit, breaker trip time, breaker duty statistics, as well as power system conditions, including overloads and unbalances and alarming for such conditions.
    b) User-defined logic points programmable as major or minor alarms.
9) Detailed sequence of events logger showing internal logic change of state for an event:
    a) With multiple oscillographic reports for currents showing pre-fault, faulted, and post-fault currents.
10) LOI that allows reading of measured values and performing basic setting changes.
    a) Capable of being programmed to automatically display and scroll user-specified information.
11) Controllable via virtual switches which are HMI or LOI addressable:
    a) Switches may be usable for on/off/pulse of any user-selected function or logic point (e.g., instantaneous element block or reclose enable).
12) 1 virtual breaker control switch, accessible locally from the LOI or remotely from the communications ports, to provide trip and close control of a selected breaker:
    a) Function: 101.
    b) 4 virtual switches with 3 modes of operation, accessible locally from the LOI or remotely from the communications ports, can be used (e.g., to trip and close additional switches or breakers, or to enable and disable certain functions).
13) Minimum of 4 hardwired control inputs:
    a) Each input programmable to represent system status, e.g., breaker position, or control any user-defined function or logic point.
    b) Minimum of 5 normally open output contacts plus 1 normally closed major/relay alarm contact.
    c) Contacts programmable to follow custom user-defined logic schemes.
    d) Minimum make and carry 30 A, 0.2 s, 6 A continuous.
    e) Break 0.3 ADC at L/R=0.04.
14) With a breaker or lockout relay trip circuit monitor to monitor for loss of voltage, fuse blown, or loss of continuity, trip coil open.

15) Meeting the isolation, surge withstand, fast transient, impulse, and radio interference standards in accordance with IEEE C37.90.1 and IEEE C37.90.2.
16) Future firmware enhancements made through flash memory.

c. Manufacturers: One of the following:
1) ABB, REF615.
2) Basler. Model BE1-11f.
3) Schweitzer, SEL-751A.

5. High-impedance bus differential relay (87B):
a. Description:
1) High-speed, high-impedance, solid state bus differential relay, providing high speed fault protection.

b. Specific requirements:
1) 3-phase current sensing zone between line-side of the switchgear's main breaker and associated feeder breakers.
2) Operation time:
a) Maximum operating time for any fault: 1.25 cycles (21 msec).
3) Sensing range input: 0.25 to 2.50 A.
4) Timing: Instantaneous or 20 msec delay.
5) CT overvoltage:
a) Alarm voltage selectable range: 10 to 80 percent in 10 percent increments.
b) Detect unbalance voltages.
c) CT overvoltage LED alarm lights.
6) Pickup voltage control:
a) Pickup voltage setting range from 50 to 400 volts in 50-volt increments.
7) Pickup current control:
a) Current setting of 0.25 to 2.50 A RMS in 0.25 A increments.
b) Setting determines the level of current sensing input resulting in the trip output contact closure.
c) With trip LED lights.
d) Operation based on the instantaneous peak value of the sinusoidal current detected.
8) Pickup current trip LED:
a) Indicates when the level of current through the relay exceeds the setting of the pickup current control.
b) Latches on until reset button is pressed.
9) Trip test pushbutton:
a) Used to simulate a trip condition to verify operation of output trip contacts, verify operation of trip LED lights.
10) CT test pushbutton:
a) Used to verify the health of the CT input circuit.
b) Provide 1 CT Diagnostic Test Source.

c. Function: 87B.
d. Manufacturers: One of the following:
1) ABB, REF615-N + 3 ph voltage dependent resistors.
2) Basler, BE1-87B:
a) Basler P/N 9282300014 - CT Diagnostic.
3) Schweitzer, SEL-587Z.

6. Current differential relay (87M, 87T):
    a. Description:
        1) Provide current differential protection with programmable single- or dual-slope percentage restraint for 2-winding transformers, reactors, generator, large motors, and other 2-terminal apparatus.
        2) Use second- and fourth-harmonic blocking or restraint along with DC blocking to supervise differential elements during transformer energization conditions.
        3) Calculate fifth harmonic to supervise differential element operations during transformer over excitation events.
        4) Solid-state relay that compare 3-phase current entering and leaving the generator.
    b. Specific requirements:
        1) Sensing input: As indicated on the Drawings.
        2) Restraint factor that is proportional to input current when the restraining current is greater than nominal by comparing the sensed input and output current and the lesser of the 2 sensed current level becomes the restraining current.
            a) Difference between the 2 sensed currents is compared to a reference established by the sensitivity setting, adjusted by an amount proportional to the restraining current, increasing the sensitivity to low current internal faults and less sensitive to external faults with high level of through current.
        3) Function: 87M.
    c. Manufacturers: One of the following:
        1) ABB:
            a) Generator: REG615-D.
            b) Transformer: RET615-B.
        2) Basler:
            a) BE1-FLEX.
        3) Schweitzer:
            a) SEL-587.
            b) SEL-710.
            c) SEL-787.
7. Instantaneous/Time overcurrent relay (50/51):
    a. Description:
        1) Microprocessor based, multifunction protective that provides instantaneous (50) and time (51) overcurrent protection for the monitoring and control of power systems equipment.
        2) 3 current inputs to measure phase current:
            a) Fundamental algorithm that responds to the fundamental component of the current and rejects the harmonic components.
            b) Measures magnitude of the negative-sequence component of the fundamental phase current.
    b. Specific requirements:
        1) Instantaneous overcurrent functions each with settable time delays: 50P, 50G, 50Q.
        2) Time overcurrent: 51P, 51G, 51Q.
        3) General purpose logic timers: 62.

4) AC current inputs:
    a) 5A nominal:
        (1) 15 A continuous; 500 A for 1 second linear to 100 A symmetrical.
        (2) Limiting dynamic value: 625 A for 1 cycle.
        (3) Burden: 0.16 VA at 5 A, 1.15 VA at 15 A.
    b) 1A nominal:
        (1) 3 A continuous; 100 A for 1 second linear to 20 A symmetrical.
        (2) Limiting dynamic value: 250 A for 1 cycle.
5) Burden: 0.06 VA at 1A, 0.18 VA at 3 A.
6) Control switches:
    a) 1 breaker control switch.
    b) 4 virtual control switches.
    c) Trip and close control of a selected breaker either locally or from HMI.
7) Metering:
    a) Measured current and derived neutral and negative-sequence currents.
    b) Demand reporting for all phases, neutral, and negative-sequence currents with user settable demand intervals.
    c) Measurement accuracy: Within 2 percent.
8) Sequence of events recorder:
    a) User-programmable.
    b) Time stamped.
9) Sensing input:
    a) 3-phase.

c. Function: 50, 51, 50/51.
d. Manufacturers: One of the following:
    1) ABB, REF615.
    2) Basler, Model BE1-851.
    3) Schweitzer, Model SEL-501.

8. Motor protection relay MPR Type 2:
    a. Description:
        1) Provides protection of medium-voltage 3-phase induction and synchronous motors using a slip-dependent thermal model.
        2) Provides locked rotor, overload, over temperature, differential protection.
        3) Provide voltage transformers, current transformers, and a digital motor protection and management relay as indicated on the Drawings.
    b. Specific requirements:
        1) Protection:
            a) Primary protective function shall be a thermal model consisting of:
                (1) Overload curves.
                (2) Negative sequence unbalance/single phase biasing.
                (3) RTD biasing (hot/cold motor compensation).
                (4) Motor cooling time constants.
                (5) Start inhibit and emergency restart.
                (6) RTD biasing.
                (7) Combine inputs from positive and negative sequence currents and RTD winding feedback.

(8) Dynamic in nature in order to follow the loading and temperature of the motor.
(9) Provide protection of the rotor during stall and acceleration:
(a) Stall/acceleration curve shall be voltage compensated.
(b) A speed switch input shall be available.
(10) INOM = 5 A secondary as indicated on the Drawings.

b) Thermal overload 49:
(1) Full-load current (FLA) Limits: 0.2 to 5,000.0 A primary (limited to 20 to 160 percent of CT rating).
(2) Locked rotor current: 2.5 to 12.0*FLA.
(3) Hot locked rotor time: 1.0 to 600.0 seconds.
(4) Service factor: 1.01 to 1.5.
(5) Accuracy: 5 percent within 25 ms at multiples of FLA greater than 2 (cold curve method).

c) Short circuit 50P:
(1) Setting range: Off, 0.10 to 20.00*FLA in 0.01*FLA increments.
(2) Accuracy: Within 5 percent of setting within 0.02* INOM RMS secondary.
(3) Maximum pickup/dropout time: 1.5 cycles.
(4) Time delay: 0.0 to 5.0 seconds in 0.01 second increments.
(5) Accuracy: Within 0.5 percent of setting within 0.25 cycle.

d) Ground fault 50G:
(1) Setting range: Off, 0.10 to 20.00*FLA in 0.01*FLA increments.
(2) Accuracy: Within 5 percent of setting within 0.02* INOM RMS secondary.
(3) Maximum pickup/dropout time: 1.5 cycles.
(4) Time delay: 0.0 to 5.0 seconds in 0.01 second increments.
(5) Accuracy: Within 0.5 percent of setting within 0.25 cycle.

e) Ground fault 50N:
(1) Setting range:
(a) 1A, 5A: Off, 0.01 to 650.00 A primary in 0.01 A RMS increments.
(b) 2.5 mA: Off, 0.01 to 25.00 A primary in 0.01 A RMS increments.
(2) Accuracy: Within 5 percent of setting within 0.05 mA secondary.
(3) Maximum pickup/dropout time:
(a) 1A, 5A: 1.5 cycles/1.5 cycles.
(b) 2.5 mA: 100 msec plus 1.5 cycles/1.5 cycles.
(4) Time delay: 0.0 to 5.0 seconds in 0.01 second increments.
(5) Accuracy: Within 0.5 percent of setting within 0.25 cycles.

f) Negative-sequence overcurrent 50Q:
(1) Setting range: Off, 0.10 to 20.00*FLA in 0.01*FLA increments.
(2) Accuracy: Within 5 percent of setting within 0.02* INOM secondary.
(3) Maximum pickup/dropout time: 1.5cycles.
(4) Time delay: 0.0 to 120.0 seconds in 0.01 second increments.
(5) Within 0.5 percent of setting within 0.25 cycle.

g) Inverse-time overcurrent phase 51P:
(1) Pickup setting range secondary:
(a) 5A: Off, 0.50 to 10.00 A in 0.01 A steps.
(b) 1A: Off, 0.10 to 2.00 A in 0.01 A steps.
(2) Accuracy: Within 5 percent of setting within 0.02-INOM secondary.
(3) Time dial: 0.50 to 15.00 in 0.01 steps.
(4) Accuracy: Within 1.5 cycles within 4 percent between 2 and 30 multiples of pickup.
h) Inverse-time overcurrent ground 51G:
(1) Pickup setting range secondary:
(a) 5A: Off, 0.50 to 10.00 A in 0.01 A steps.
(b) 1A: Off, 0.10 to 2.00 A in 0.01 A steps.
(2) Accuracy: Within 5 percent of setting within 0.02-INOM secondary.
(3) Time dial: 0.50 to 15.00 in 0.01 steps.
(4) Accuracy: Within 1.5 cycles within 4 percent between 2 and 30 multiples of pickup.
i) Inverse-time overcurrent negative-sequence 51Q:
(1) Pickup setting range secondary:
(a) 5A: Off, 0.50 to 10.00 A in 0.01 A steps.
(b) 1A: Off, 0.10 to 2.00 A in 0.01 A steps.
(2) Accuracy: Within 5 percent of setting within 0.02-INOM secondary.
(3) Time dial: 0.50 to 15.00 in 0.01 steps.
(4) Accuracy: Within 1.5 cycles within 4 percent between 2 and 30 multiples of pickup.
j) Differential protection 87M:
(1) Setting range: Off, 0.05 to 8.00 A secondary.
(2) Accuracy: Within 5 percent of setting within 0.10 A secondary.
(3) Maximum pickup/dropout time: 1.5 cycles.
(4) Accuracy: Within 0.5 percent of setting within 0.25 cycle.

c. Manufacturers: One of the following:
1) ABB, REX640B10NN+AIM2+AIM2+ADD1+APP7+ARC1+BIO2+CMP2+COM4+LNG1+MCT2+PCL1+PSM2+RTD1+SCT1:
a) Additional 2 RTD inputs, 2 mA inputs, 4 mA outputs with RIO600 (PSMH+LECMIR+RTD4+AOM4) modules.
b) RIO600 communication with REX640 via RJ45 Ethernet port.
2) Schweitzer, SEL-710-5.

d. Transformer differential relays:
1) Provide the following functions as a minimum:
a) Phase time overcurrent: 51P.
b) Phase instantaneous overcurrent: 50P.
c) Ground time overcurrent: 51G.
d) Ground instantaneous overcurrent: 50G.
e) Differential current: 87.
2) Provide multiple relays where necessary to meet the required protective functions and the zone interlocking capability.

3) Manufacturers: One of the following:
   a) ABB, RET615.
   b) Basler, BE1-CDS-220/BE1-1051.
   c) Schweitzer, SEL-587-1/SEL-351S.

## 2.08 ACCESSORIES

A. Current transformers:
   1. Ring type:
      a. Suitable for service within low or medium voltage switchgear as indicated on the Drawings.
      b. Designed to have a mechanical and thermal rating to withstand short-circuit current, stresses, and heating effects equal to the rating of the circuit breaker of the application.
   2. Current ratio: As indicated on the Drawings, for use as a guideline:
      a. It is the switchgear manufacturer's responsibility to size the current transformers to ensure that they will not saturate under the maximum available fault current at the installed location based upon the short-circuit fault analysis as preformed as specified in Section 26_05_74 - Electrical System Studies.
   3. Rated in accordance with IEEE C57.13 with accuracy of the current transformers suitable for relay accuracy class and rated for 200 percent burden for the required connected devices.
   4. Identify polarity with standard marking or symbols.
   5. Capable of carrying rated primary current continuously without damage.
   6. Install secondary wiring from current transformers in a suitable wiring trough, or conduit to proper short-circuiting type terminal blocks for connection to relays, instruments, and other devices.

B. Voltage transformers:
   1. Indoor dry type, single-phase, 60 hertz, with a minimum thermal capacity of not less than 400 volt-amps at 131 degrees Fahrenheit rise above 104 degrees Fahrenheit ambient.
   2. Accuracy classification in accordance with IEEE C57.13, suitable for relay accuracy class, and 200 percent burden, for the required connected devices, with the secondary voltage 120 volts.
   3. Insulation levels as required for the switchgear system voltage but not less than:
      a. 600 VAC, 10 kV BIL for 480 VAC systems.
      b. 5.6 kV, 60 kV BIL for 2300 and 4160 VAC systems.
      c. 15.5 kV, 110 kV BIL for 12.47 kV and 13.2 kV systems.
   4. Identify polarity with standard markings or symbols.
   5. Connect secondaries to voltage buses as required.
   6. Provide primary and secondary current-limiting fuses.

C. Test blocks and plugs:
   1. Make-before-break connections for CT circuits.
   2. Provide cover for each test block.
   3. Manufacturers: One of the following or equal:
      a. ABB, FT-1:
         1) 10-pole test switch.

b. Multilin, PK-2:
    1) Current circuits: 6-pole test blocks.
    2) Voltage circuits: 4-pole test blocks.

D. Satellite-synchronized clock:
1. Provide a master clock to synchronize the clock functions of the protective relays:
    a. IEEE 1588 PTP clock for IEC 61850-9-2LE.
2. Surge standards:
    a. IEEE C37.90.
    b. IEC 60255.
3. Power supply: 125 VDC:
    a. Burden: Less than 15 W, less than 35 VA.
4. Output: 6 unmodulated IRIG-B time-code outputs:
    a. User-selectable for 1 PPS,1 kPPS,IRIG-B.
    b. IRIG Standard 200-02, Format B006.
    c. Fiber-optic port:
        1) ST connections.
        2) Multiplexes an unmodulated IRIG-B signal on the data communications signal.
        3) 9,600 bps.
5. Operating temperature: -40 degrees Fahrenheit to 176 degrees Fahrenheit.
6. Altitude: 2,000 m (6,500 ft) AMSL.
7. Clock accuracy to UTC time:
    a. 1 PPS: Within 100 ns average, within 500 ns peak.
    b. Unmodulated IRIG-B: Within 100 ns average, within 500 ns peak.
    c. Modulated IRIG-B: Within 1 µs peak.
    d. Serial Port BX command: Within 500 µs peak.
    e. Holdover stability: Within 0.08 ppm for 20 minutes (from -40 degrees Fahrenheit to 176 degrees Fahrenheit).
8. Antenna:
    a. GPS GNSS:
        1) 5 V, less than 80 mA.
        2) 35 dB preamp.
    b. Mounting:
        1) Unobstructed 360-degree view of sky.
        2) Low and close to the control house roof, above the maximum snow accumulation level.
    c. Surge protector:
        1) Equalize the difference in voltage that can occur between the center conductor and the shield of the coaxial cable between the antenna and the clock.
        2) Located at building enclosure entrance.
        3) Ground the surge protector and clock to the same point.
        4) TNC female antenna connected.
    d. Display:
        1) Front-panel LEDs show clock progress from start to satellite lock.
        2) Display: Ordinal day of the year: HH:MM:SS.
        3) Indicators:
            a) Enabled.

b) Satellite Lock.
c) Holdover.

9. Manufacturers: The following:
   a. Basler.
   b. Schweitzer:
      1) Clock: SEL-2407.
      2) Antenna: SEL-9524A GPC GNSS.
      3) Surge protector: SEL Surge Protector Kit 915900139.
      4) Cable: SEL-C961.

E. Real time process controller:
   1. General:
      a. Information processor operating both serial and Ethernet communications network:
         1) Providing the following functions:
            a) Deterministic logic processing.
            b) Automatic transmission of outgoing messages.
            c) Processing of responses.
            d) Data scaling.
            e) Data aggregation.
            f) Simultaneous collection of data from multiple server devices for various manufacturers.
            g) Simultaneous data access for multiple client (master) devices.
      b. Suitable for use in utility substations or industrial control and automation systems.
      c. Provides control with integrated security, seamless configuration, unified logic, and reliability.
      d. Converts data between multiple protocols, communicates with any configured and connected device with an embedded IEC 61131 logic engine.
      e. 32-bit microcontroller for protective relay-speed I/O, logic, and communications.
      f. Precision time protocol (PTP) and demodulated IRIG-B input that synchronizes connected intelligent electronic devices (IEDs) to absolute time and drives the demodulated IRIG-B output, enabling synchronized control and management.
   2. Protocols:
      a. Provide the following:
         1) FTP.
         2) SFTP.
         3) DNP3 serial.
         4) DNP3 LAN/WAN.
         5) IEC 61850 MMS.
         6) Modbus RTU.
         7) Modbus TCP.
         8) LG 8979.
         9) IEEE C37.118.
         10) IEC 60870-5-101/104.
         11) SES-92.

b. Client:
    1) CP2179.
    2) Flex Parse.
    3) SEL ASCII and Binary.
    4) SNMP.
    5) DNP3 serial.
    6) DNP3 LAN/WAN.
    7) IEC 61850 MMS.
    8) Modbus RTU.
    9) Modbus TCP.
    10) LG 8979.
    11) IEEE C37.118.
    12) IEC 60870-5-101/104.
    13) SES-92.
    14) EtherCAT.
c. Peer-to-peer:
    1) IEC 61850 GOOSE transmit and receive messages.
    2) Parallel Redundancy Protocol.

3. CPU:
    a. Error correcting code (ECC) RAM information processor.
4. Intelligent and secure components:
    a. Electronic equipment continuously self-testing and reports internal errors, including a hardwire contact indicating device health.
5. Programming:
    a. Integrated IEC 61131-3 programming environment for the information processor, with the ability to continuously monitor and control every protective relay and Ethernet-distributed I/O module in the electrical system.
    b. IEC 61131-3 programming environment integrated in 1 software package with the communications protocol mapping environment.
6. Role-based security:
    a. Independent user-based security with strong passwords, role-based accounts, and settable account expiration dates.
    b. Provide a mechanism to map security-related system tags into HMI reports.
7. Integrated HMI:
    a. Integrated web-based human-machine interface (HMI) that provides visualization and control of data tags.
8. Central authentication:
    a. Lightweight directory access protocol (LDAP) to provide central user account authentication.
9. Selectable processing interval and solve order:
    a. Provide a method to configure the deterministic processing interval for protocol communications and custom logic, including a method to configure the processing sequence of software tasks.
    b. Processing interval settable to as fast as 1 ms.
10. High-speed peer-to-peer communication:
    a. Utilizing MIRRORED BITS® communications protocol to transmit and receive high-speed digital data to/from intelligent electronic devices (IEDs) to create custom protection and control schemes.

11. Communications:
    a. Serial ports:
        1) Each port software configurable for RS-232 or RS-485 communications modes.
    b. Ethernet ports:
        1) 2 or more Ethernet ports that can operate simultaneously on different networks through independent MAC addresses.
        2) Ports configurable as fiber-optic or copper Ethernet ports.
12. Alarm output:
    a. Programmable dry contact output to signal internal errors and malfunctions, as well as additional conditions.
13. Environmental testing:
    a. Information processor tested to IEEE 1613-2003 for communications and networking equipment in electric power substations, and to the same standards as protective relays, including the following:
        1) Cold:
            a) IEC 60068-2-1:2007.
            b) IEC 61850-3:2013.
            c) IEEE 1613-2003.
            d) Severity level: 16 hours at -40 degrees Celsius.
        2) Damp heat, cyclic:
            a) IEC 60068-2-30:2005.
            b) IEC 61850-3:2013.
            c) IEEE 1613-2003.
            d) Severity level: 12 + 12-hour cycle, 25 degrees Celsius to 55 degrees Celsius, 6 cycles, 95 percent relative humidity.
        3) Dry heat:
            a) IEC 60068-2-2:2007.
            b) IEC 61850-3:2013.
            c) IEEE 1613-2003.
        4) Vibration:
            a) IEC 60255-21-1:1988.
            b) IEC 61850-3:2013:
                (1) Severity level: Endurance Class 2, Response Class 2.
            c) IEC 60255-21-2:1988:
                (1) Severity level: Shock Withstand, Bump Class 1, Shock Response Class 2.
            d) IEC 60255-21-3:1993:
                (1) Severity level: Quake Response Class 2.
            e) IEEE 1613-2003:
                (1) Severity level: V.S.4.
14. Synchrophasors:
    a. Capable of receiving synchronized phasor measurement data via the IEEE C37.118 protocol on serial and Ethernet ports to as fast as 5 messages per second.
15. Retained memory:
    a. Nonvolatile memory available for user-programmable retained variables.
16. Engineering access:
    a. Transparent connections between any serial or Ethernet communications ports for engineering access.

17. Conformal coating:
    a. Of the circuit boards.
18. Reliability:
    a. Submit actual measured mean time between failures (MTBF) for the device.
19. Service:
    a. Manufacturer provided no-cost technical support for the life of the product.
    b. Manufacturer to support a 72-hour turn-around on warranty repairs.
20. SEL-2240 Axion®:
    a. Deterministic ethernet fieldbus:
        1) Utilizing EtherCAT protocol to operate a deterministic, Ethernet-based fieldbus network for connected I/O modules.
    b. Digital inputs sequential events:
        1) Maintain a user-configurable record of digital input operations on the EtherCAT network that is accurate to 1 ms.
    c. DC analog inputs:
        1) Include up to 16 DC analog input modules.
        2) Input ranges: Within 20 mA.
    d. DC analog outputs:
        1) Include up to 16 DC analog output modules.
        2) Output ranges: Within 20 mA.
    e. AC metering inputs:
        1) Include up to 16 CT/PT analog input modules.
        2) Input ranges:
            a) CT: 0 to 22 A.
            b) PT: 5 to 400 V.
    f. AC protection inputs:
        1) Include up to 16 CT/PT protection modules.
        2) Input ranges:
            a) CT: 0 to 20 A.
            b) PT: 6 to 300 V.
    g. Redundant power supply:
        1) Provide 2 power supply modules that continuously share load.
        2) If the incoming power for 1 module becomes unavailable, the remaining power supply shall have sufficient capacity to accommodate an entire node.
21. Manufacturers: The following:
    a. Schweitzer:
        1) SEL-3530.

F. Control wiring:
    1. As specified in the electrical equipment specifications.

G. Miscellaneous:
    1. Provide terminal blocks, wireways, wiring, device mounting brackets, and other miscellaneous items.

## PART 3 EXECUTION

### 3.01 EXAMINATION (NOT USED)

### 3.02 PREPARATION (NOT USED)

### 3.03 INSTALLATION (NOT USED)

### 3.04 FIELD QUALITY CONTROL

A. Manufacturer's services:
   1. Provide the services of a qualified relay manufacturer's representative to test:
      a. Differential protection schemes.
      b. Utility paralleling schemes.
      c. Complete testing of the power management system confirming the calibration, accuracy, and communications.

### 3.05 OWNER TRAINING

A. Perform Owner Training as specified in Section 01_75_17 - Commissioning.

### 3.06 ADJUSTING

A. Protective relay programmer to adjust trip settings in accordance with the protective device coordination study as accepted by the Engineer and in accordance with the protective relay manufacturer's recommendations:
   1. Export settings to a standard format that is reviewable for the Engineer (i.e., .csv file, etc.). Submit for review as specified in this Section.

END OF SECTION

## SECTION 26_18_42

## MEDIUM VOLTAGE VARIABLE FREQUENCY DRIVE

### PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Medium voltage variable frequency drive (VFD) system.

### 1.02 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):
   1. 18 - Standard for Shunt Power Capacitors.
   2. 519 - IEEE Standard for Harmonic Control in Electric Power Systems.
   3. 1036 - IEEE Guide for the Application of Shunt Power Capacitors.
   4. C57.12.01 - IEEE Standard for General Requirements for Dry-Type Distribution and Power Transformers.
   5. C57.16 - IEEE Standard for Requirement, Terminology, and Test Code for Dry-Type Air-Core Series-Connected Reactors.
   6. C62.11 - Standard For Metal-Oxide Surge Arresters For AC Power Circuits (>1 kV).

B. International Organization for Standardization (ISO):
   1. 9001 - Quality Management Systems - Requirements.

C. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).

D. Underwriters Laboratories, Inc. (UL).

### 1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Point of common coupling (PCC): The point of common coupling for harmonic calculations and field measurements for both voltage and current distortion shall be defined as the primary connection of each VFD input isolation transformer.
   2. VFD manufacturer, Supplier and VFD supplier shall be defined as the same entity for the purposes of this document.

### 1.04 SUBMITTALS

A. Furnish Submittals as specified in Section 01_33_00 - Submittal Procedures:
   1. Custom prepared by the VFD system manufacturer for this specific application and edited for the equipment furnished.

B. Product data:
   1. Manufacturer of VFD.
   2. Manufacturer of component parts of VFD.
   3. Dimensions:
      a. Height.
      b. Length.
      c. Width.
      d. Weight.
   4. Nameplate schedule.
   5. Bill of material.
   6. Description of operation:
      a. Metering system.
      b. Protective relaying.
   7. Ratings:
      a. Voltage.
      b. Phase.
      c. Input current.
      d. Output current.
      e. Interrupting rating (circuit breakers and fuses):
         1) Furnish manufacturer's time current curves on 11- by 17-inch log-log paper for fuses.
      f. Momentary current rating.
   8. List of recommended spare parts.
   9. Lightning arrester data.
   10. Name of dealer's repair facility and parts stocking agreement with the factory:
      a. Agreement shall outline in detail the manufacturer's parts stocking requirements and the method by which the manufacturer's representative verifies that the stock is at an acceptable level.
      b. Agreement should also outline the method by which the manufacturer's representative determines that the service personnel meet factory standards.
   11. For equipment installed in structures designated as seismic design category C, D, E, or F, submit the following as specified in Section 01_81_50 - Design Criteria:
      a. Manufacturer's statement of seismic qualification with substantiating test data.
      b. Manufacturer's special seismic certification with substantiating test data.

C. Shop Drawings:
   1. Layout drawings:
      a. Fully dimensioned and to scale equipment layout drawings which include:
         1) Equipment furnished.
         2) Interfaces with all other equipment.
         3) Dimensions.
         4) Shipping splits.
         5) Panel, sub-panel, and component layout indexed to a complete bill of material:
            a) Front panel.
            b) Sub-panels.
            c) Interior panels.
         6) Conduit windows.

2. Complete schematic, wiring and interconnection drawings.
3. Complete electrical wiring diagrams:
    a. Point-to-point connections.
    b. With wire numbers.
4. Complete interface and connection diagrams for metering and relaying system.
5. Plan, front, and side view drawing, including overall dimensions and bus layout of each VFD. Identify shipping splits and show conduit stub-up area locations.
6. Internal schematics, elementary diagrams, and wiring diagrams of each unit or compartment, including wiring identification and terminal.
7. Complete 1-line diagrams and 3-line diagrams for each VFD:
    a. Drawings shall indicate devices comprising the switchgear assembly, including, but not limited to, circuit breakers, control power and instrument transformers, meters, relays, control devices and monitoring devices.
    b. Device electrical ratings shall be clearly indicated on the Drawings.
8. Assembly drawings, cross-section as a minimum, for each VFD with major dimensions indicated.
9. Design data:
    a. Block diagram showing the basic control and protection systems specifying the protection, control, trip and alarm functions at the different locations, the reference signals and commands and the auxiliary supplies (i.e., air, oil, cooling water, electrical auxiliary supplies).
    b. Electrical single line diagram showing main and auxiliary circuitry, including main power input, switchgear, transformer, VFD, system grounding and auxiliary supplies - showing CTs, PTs, relays, meters, etc., for the control, protection, and operation of the drive system with electrical data (i.e., voltage, current, time ratings, impedances, tolerances).
    c. Efficiency and power factor values.
    d. Harmonic distortion analysis.

D. Calculations:
1. Torsional analysis:
    a. The price of the torsional analysis shall be included in the base price of the VFD system:
        1) Total rotating system shall be analyzed to determine its natural resonant frequencies.
        2) Stresses are to be calculated for elements of the rotating system, utilizing torsional excitation data from the drive and driven system, taking into account potential fault conditions, and appropriate amplification and damping factors of the rotating system.
        3) A written report on the analysis shall detail the procedures used and the assumptions that were considered shall be provided.
        4) Results of the analysis must be presented in both detailed and summary form. Specific data presented shall include the following:
            a) A diagram of the frequencies of the torque pulsations and the mechanical resonant frequencies showing their coincident points.
            b) A plot of total shaft stress versus operating speed for the most highly stressed areas of the rotating system.
            c) A diagram of the rotating system model and mode shapes for resonance(s) of interest.

d) Tables summarizing total calculated stresses for each element of the rotating system at operating speeds where interference(s) exist between torsional excitation and torsional resonance.
e) Details of the rotating system used in the analysis, including the specified or a recommended alternate coupling.
f) Recommendations for any modifications to the proposed system, if indicated by the analysis to be advisable, which cost shall be borne by the VFD system manufacturer.

2. Harmonic study:
   a. A preliminary harmonic analysis shall be performed. A power system short circuit ratio of 10 shall be assumed, with all VFDs operating at maximum speed and maximum load. Short circuit current (ISC) utilized for harmonic analysis calculations is defined as:
      1) $I_{sc}$ = 10 * (Sum of total full load amps of all VFD system).
   b. Harmonic analysis must be submitted by the VFD system manufacturer at the time of bid, which includes all voltage and current harmonics up to the 99th. Harmonic analysis must be performed at the defined point of common coupling.

E. Installation instructions:
   1. Detail the complete installation of the equipment, including rigging, moving, and setting into place.
   2. Provide manufacturer's installation instructions.

F. Quality Control Submittals:
   1. Manufacturer's representative qualifications.
   2. Manufacturer's Certificate of Source Testing as specified in Section 01_75_17 - Commissioning.
   3. Manufacturer's Certificate of Installation Verification as specified in Section 01_75_17 - Commissioning.
   4. Test reports.
   5. Report listing the setting of VFD adjustable parameters and their values after start-up.

G. Owner Training Submittals:
   1. As specified in Section 01_75_17 - Commissioning.

H. Certificates:
   1. Certification that the drive is sized for the full motor horsepower and amperage at the installed altitude.
   2. Efficiencies meet the requirements specified in this Section.
   3. VFD system proposed has been in operation for a minimum of 3 years.

I. Operation and maintenance manuals:
   1. As specified in Section 01_78_24 - Operation and Maintenance Manuals.
   2. Spare parts list with supplier names and parts numbers.
   3. Startup and commissioning instructions and data.
   4. Operating manuals:
      a. Submit operating instructions and a maintenance manual presenting full details for care and maintenance of equipment of every nature furnished and/or installed under this Contract.

5. Operating instructions:
    a. Written descriptions must detail the operational functions of all normally used controls, placed on the front panel of the switchgear.
6. Maintenance manual:
    a. Furnish with instructions covering details pertaining to care and maintenance of equipment, as well as data identifying all parts.
    b. These manuals shall include, but are not limited to, the following:
        1) Adjustment and test instructions covering the steps involved in the initial test, adjustment and start-up procedures.
        2) Detailed control instructions, which outline the purpose and operation of every control device used in normal operation.
        3) Schematic, wiring and external diagrams:
            a) Drawings shall be furnished in a reduced 11- by 17-inch format and shall be fully legible at the drawing size.

## 1.05 QUALITY ASSURANCE

A. Qualifications:
1. Any third-party certification, safety, or protection requirements shall be applied to the VFD system as a whole. Certification or protection of system elements or individual components by themselves is not acceptable.
2. VFD manufacturer shall be able to demonstrate at least 10 years of experience in manufacturing medium voltage VFDs, to demonstrate their capability to provide parts and service support:
    a. A user's list of similar design equipment, complete with contact names and telephone numbers, shall be furnished.

B. Regulatory requirements:
1. VFDs shall be manufactured, assembled, tested, and provided with UL label.
2. Adjustable frequency drives shall be manufactured by the VFD manufacturer at its own facility, which shall have a quality assurance program that is certified in conformance with ISO Standard 9001.

C. Certificates:
1. It is the intention of this document to specify dependable and reliable equipment offering the best performance available from currently proven technology. Equipment furnished under this Contract must therefore have documentation showing proof of actual operation for a minimum of 3 years in similar service:
    a. New components or design topologies that have less than 3 years of actual operating experience will not be acceptable.

## 1.06 DELIVERY, STORAGE, AND HANDLING

A. Packing, shipping, handling, and unloading:
1. VFD system shall be delivered to the Site pre-assembled and wired with specified interconnecting wiring and cable:
    a. Cabling for connection across shipping splits shall be neatly coiled and identified.
    b. Exposed sections of equipment shall be fully protected from damage during shipment.
    c. Necessary hardware for reconnecting shipping splits shall be provided.

2. Complete instructions for handling and storage shall be provided before delivery of the equipment:
    a. Equipment shall have adequate provisions for handling by overhead crane or forklift truck.
3. VFDs shall be shipped to the Site in dedicated air ride vans.

B. Acceptance at Site:
1. Upon arrival at the Site, the Contractor and the VFD manufacturer shall inspect the equipment and identify any shortcomings or damage.
2. Repair damage and correct shortcomings within 30 days of delivery at the Site.

C. Furnish temporary equipment heaters within the switchboard to prevent condensation from forming.

## 1.07 PROJECT OR SITE CONDITIONS

A. As specified in Section 01_81_50 - Design Criteria.

## 1.08 ADMINISTRATIVE REQUIREMENTS

A. Sequencing:
1. Conduct the initial short-circuit fault analysis as specified in Section 26_05_74 - Electrical System Studies and submit results for the Engineer's review.
2. After successful review of the initial short-circuit fault analysis, submit complete equipment Submittal.
3. Conduct factory acceptance test and submit certified test results for the Engineer's review.
4. Ship equipment to Project Site after successful completion of factory acceptance test.
5. Conduct field acceptance test and submit results for the Engineer's review.
6. Submit manufacturer's certification that equipment has been properly installed and is fully functional for the Engineer's review.
7. Conduct Owner Training sessions.
8. Commissioning and process start-up as specified in Section 01_75_17 - Commissioning.

B. VFD manufacturer shall coordinate with the manufacturer of the driven equipment to develop the proper equipment protection and settings.

## 1.09 WARRANTY

A. As specified in Section 01_78_36 - Warranties and Bonds.

## 1.10 SYSTEM START-UP

A. VFD system manufacturer shall be responsible for starting up the VFD in the presence of the driven equipment manufacturer, motor manufacturer, Engineer, and Owner.

B. Any difficulties or problems that arise as a result of start-up shall be documented by the VFD manufacturer and corrected within 5 working days at no cost to the Owner.

## 1.11 MAINTENANCE

A. Maintenance service:
   1. VFD manufacturer shall provide maintenance service throughout the warranty period at no additional cost to the Owner:
      a. Maximum response time to a maintenance call shall not exceed 24 hours.

B. Extra materials:
   1. The following spare parts shall be furnished:
      a. 3 of each type of power and control fuse.
      b. 4 of each type of power semiconductor (SCR, GTO, IGBT, IGCT, power diode, etc.) used in the converter/rectifier or inverter.
      c. 8 of each type or size of DC link capacitor.
      d. 2 of each type or size of input and output filter capacitor.
      e. 5 of each type of panel lamp.
      f. 1 keypad.
      g. 1 fiber optic connector of each type.
      h. 1 set of replacement air filters.
      i. For VFDs with belt driven blowers, 1 set of belts.
      j. 1 of each control printed circuit board, 2 of each type gate firing boards. Include diagnostic system printed circuit boards.
      k. 1 complete spare low voltage power tray for drives that use multiple power low voltage power trays to develop the medium voltage output.
   2. Parts supplied with the equipment shall be properly labeled for ease of identification and to permit the shortest possible time to repair:
      a. Any parts that come from a sub-supplier shall be labeled with that manufacturer's name and part number.
   3. Manufacturer shall state closest point where spare parts are stocked and where service can be obtained:
      a. Minimum response time for trouble calls shall be 2 hours.
      b. A qualified service technician shall be on site within 24 hours of a qualified request.
   4. Manufacturer shall warrant that all parts shall be available for a minimum of 10 years.

# PART 2 PRODUCTS

## 2.01 GENERAL (NOT USED)

## 2.02 DESIGN AND PERFORMANCE CRITERIA

A. Provide equipment and components that are fully rated for the Site elevation and operating environment where the equipment will be installed as specified in Section 01_81_50 - Design Criteria and as indicated on the Drawings.

B. Design requirements:
   1. Each VFD system shall consist of system components required to meet the performance, protection, safety, testing, and certification criteria as specified in this Section. These components include, but are not limited to, incoming harmonic filter/power factor correction unit, input isolation transformer, VFD converter/direct current-link/inverter, and output filter.
   2. VFD system shall include material necessary to interconnect any VFD system elements, even if shipped separately.
   3. Any modifications to a standard product provided to meet this Section should only be performed by the VFD manufacturer.
   4. VFD system shall be completely factory pre-wired, assembled, and then tested as a complete package by the VFD manufacturer, to ensure a properly coordinated, fully integrated drive system.

C. Performance:
   1. Operating envelope:
      a. Speed and torque requirements:
         1) Provide a variable torque or constant torque VFD as required by the driven load.
         2) VFD shall be capable of producing a variable alternating voltage/frequency output to provide continuous operation over the 40 to 110 percent (25 to 66 hertz) speed range.
      b. Current requirements:
         1) Provide 100 percent of rated output current on a continuous basis.
         2) Variable torque VFD:
            a) Minimum 110 percent current overload for 1 minute.
         3) Constant torque VFD:
            a) Minimum 150 percent current overload for 1 minute.
      c. VFD must be capable of sustained operation at 10 percent speed to facilitate checkout and maintenance of the driven equipment.
      d. As a commissioning and troubleshooting feature, the VFD power circuit shall be capable of operating without a motor connected to the VFD output.
      e. Provide full rated torque at standstill and be capable of sustaining that level of torque indefinitely.
   2. Harmonics:
      a. VFD shall be in accordance with IEEE 519 for total harmonic and current distortion calculations and measurements and meet the following distortion limits:
         1) Voltage harmonics: Individual or simultaneous operation of the VFD(s) shall not add more than 3 percent total harmonic voltage distortion THD, while operating from the utility source at the input terminals of the VFD system.
         2) Current harmonics: Maximum allowable total harmonic current distortion limit, TDD, for each VFD shall not exceed 5 percent as measured at the input terminals of the VFD system.

D. Motor compatibility:
   1. VFD system shall produce output waveform that will allow utilization of standard alternating current squirrel cage induction motors, without need of any special insulation, requiring additional service factor, or derating:
      a. Motor life expectancy shall not be compromised in any way by operation with the VFD system:
         1) VFD system must comply with all elements of the output harmonics article of this Section.
      b. To ensure that that there are no problems with motor heating, VFD output current waveform shall be inherently sinusoidal at all speeds, with a total harmonic current distortion not exceeding 3 percent between 10 percent and 100 percent speed regardless of loading.
   2. VFD must provide motor overload protection under all operating conditions.
   3. System design shall not have any inherent output harmonic resonance in the operating speed range.
   4. VFD output shall produce no electrically induced pulsating torque to the output shaft of the mechanical system; thereby eliminating the possibility of exciting a resonance caused by VFD induced torque pulsations:
      a. VFD systems which produce torque pulsations in excess of 1 percent will require a torsional analysis to be supplied by the VFD manufacturer as part of the scope of supply.
      b. Price of the torsional analysis shall be included in the base price of the VFD.
      c. If the torsional analysis shows that a special coupling is required, the VFD supplier shall be required to pay the total additional cost associated with such couplings, at no additional cost to the Owner.
   5. VFD shall inherently protect motor from high-voltage dv/dt stress, independent of cable length to motor:
      a. VFD shall not require nonstandard insulation systems or insulation ratings above the VFD output voltage rating.
      b. VFD system shall be designed to produce no standing waves or over-voltage conditions based on a cable length of at least 2,000 feet (approximately 600 meters).
      c. If the VFD requires an output filter to meet this requirement, it shall be an integral part of the VFD system and included within the VFD enclosure, and included in the VFD efficiency calculation.
   6. An input transformer shall be included to provide common mode voltage protection and allow the use of a standard motor:
      a. Special high-voltage motor insulation is not an acceptable method for protection against common mode voltages.

E. VFD system efficiency:
   1. Guaranteed minimum total VFD system efficiency ($\eta_{sys}$) shall be no less than 96 percent at 100 percent speed and 100 percent load and 95 percent at 80 percent speed and 50 percent load:
      a. Efficiency evaluation shall include input transformer, harmonic filter and power factor correction, VFD converter, output filter and output transformer as indicated below.

b. Auxiliary controls such as internal VFD control boards, cooling fans, or pumps shall be included in loss calculations:
1) VFD system efficiency shall be calculated as follows:

$$\eta_{sys} = \eta_{VFD} * \eta_{xfmri} * \eta_{pfc} * \eta_{harm} * \eta_{filter} * \eta_{xfmro}$$

Where:

$\eta_{VFD}$ = Efficiency of the VFD converter/inverter

$\eta_{xfmri}$ = Efficiency of the input transformer

$\eta_{pfc}$ = Efficiency of the power factor correction

$\eta_{harm}$ = Efficiency of the input harmonic filter

$\eta_{filter}$ = Efficiency of the output filter

$\eta_{xfmro}$ = Efficiency of the output transformer

c. Note: If the motor power factor is poor (less than 0.85 at rated load), causing the VFD to provide higher than normal reactive current to the machine, the required total VFD system efficiency requirement may be reduced by 0.5 percent.

2. A factory test shall be performed at the VFD manufacturer's facility certifying that efficiencies have been met:
a. A penalty of $1,000 per kilowatt will be assessed if efficiency is not achieved and will be deducted from the Contract price.

F. System input power factor:
1. VFD system shall maintain a 95 percent minimum true power factor from 30 percent to 100 percent of rated speed.
2. VFD system, including power factor correction and/or harmonic filter, shall never have a leading power factor under utility or generator operation.
3. VFD manufacturer is to supply a power factor correction system, if required, to meet this requirement:
a. Unit shall include a separate input isolating contactor with fuses, power factor correction grade capacitors, voltage class shall be consistent with the VFD system input voltage, and series harmonic de-coupling reactors, all integrated into VFD system and mounted within the VFD enclosure.
4. A penalty of $1,000 per kilovolt-ampere of drive rating will be assessed if power factor is not achieved and will be deducted from the Contract price.

G. Speed regulation:
1. Unless otherwise specified on the data sheet, VFD speed regulation shall be within 0.5 percent without encoder or tachometer feedback.

H. Sound level:
1. Maximum allowable audible noise from the VFD system will be 75 dBA at a distance of 1 meter (3.3 feet) at any speed or load condition.
2. VFD systems with audible noise in excess of this limit must be provided with sufficient noise abatement treatment to reduce the sound pressure level below 75 dBA.

I. Space limitations - footprint:
1. VFD system must fit in the space indicated on the Project Drawings.

J. Doors:
   1. Provide snake-skin cable management sleeve or spiral wire-wrap wires where they pass from the interior of the cabinet past the door hinge to door-mounted devices.

## 2.03 MANUFACTURERS

A. One of the following or equal:
   1. Allen-Bradley.
   2. Siemens-Robicon, Harmony Series Medium Voltage Drive.
   3. Toshiba, T300MV2.

## 2.04 MATERIALS (NOT USED)

## 2.05 MANUFACTURED UNITS (NOT USED)

## 2.06 EQUIPMENT

A. VFD converter section shall be 24 pulse or more, or equivalent harmonic performance with active filters. Active harmonic filters are acceptable if they are so designed as to eliminate the necessity to modify the filters to avoid resonance problems and correct tuning whenever other inductive/capacitive loads are placed on the system or when the power system changes.

B. Power quality metering shall be installed in the VFD system to continuously monitor and display input and output power quality. Data shall include the following:
   1. Input voltage average RMS value.
   2. Input current, individual phase RMS values and average RMS value.
   3. Input frequency.
   4. Power factor.
   5. Input kilowatt, kVAR.
   6. Input kilowatt hour.
   7. Input current THD, average of 3 phases.
   8. Single harmonic calculation in input voltage and current, phases A, B, or C.
   9. Drive efficiency.
   10. RMS motor voltage.
   11. RMS motor current.
   12. Motor speed in revolutions per minute or percent.
   13. Motor flux percent.
   14. Motor torque in percent.
   15. Drive output power (kilowatt).
   16. Output kilowatt hour.

C. Firing signals:
   1. Internal firing signals and other communications, which link operational controls with power components such as status and diagnostic signals, must meet noise immunity and safety requirements as defined by applicable IEEE Standards.

D. Failed switch bypass/ride-through capability:
   1. Failure of any power switching device (SCR, GTO, diode, IGBT, IGCT, etc.) or switching device control shall not result in a process trip and shall allow for continued operation of the VFD system. In the event of a device or device control failure, the VFD shall annunciate and identify the specific location of the failed device and allow for continued operation, although at a reduced capacity, until such time as repairs can be scheduled.

E. Power interrupt ride-through:
   1. VFD system must be capable of continuous operation in the event of a power loss of 5 cycles or less.
   2. VFD system must be capable of automatically restarting in the event of a momentary loss of power:
      a. VFD system shall provide the user with the choice of automatically restarting or not.
      b. User shall be able to selectively apply this feature and have the ability to set the allowable restart time applicable to some, but not necessarily all, conditions as determined by the user to be appropriate for the specific application.

F. Power sag ride-through:
   1. VFD system shall be capable of continuous operation with 30 percent voltage sag on the input power line.

G. “Catch-a-spinning-load” capability:
   1. VFD system must be able to catch and take control of a spinning load if started while rotating equipment is already spinning.
   2. Appropriate safeguards must be included in this operation to prevent damaging torque(s), voltages, or currents from impacting any of the equipment.
   3. User shall have the option of employing this feature or disabling it.

H. Auto-restart capability:
   1. VFD system must be capable of automatically restarting in the event of a process or drive trip.
   2. VFD system shall provide the user with the choice of automatically restarting or not.
   3. User shall be able to selectively apply this feature to some, but not necessarily all, conditions as determined by the user to be appropriate for the specific application.

I. Ground fault withstand:
   1. In the event of a ground fault, the VFD shall be capable of annunciating the ground fault condition, safely operating and, by user selection, either trip or continue operation.
   2. As a result of a ground fault trip, the VFD shall be capable of being reset and operating normally.
   3. There shall be no risk of fire or electric shock as a result of the ground fault.

J. Interlocks:
   1. Mechanical key interlocks shall be provided on doors.

2. Interlocking shall be fully coordinated to prevent access to high voltage compartments, including transformer, filters, or any switchgear that is part of the supply, when line power is applied to the VFD system.
3. Must be mechanical to provide positive lock-out prevention and safety:
    a. Electrical interlock switches alone are not acceptable.

K. Control power:
1. VFD system shall internally derive necessary control power for the VFD cooling system and VFD low voltage control circuits.
2. Supplied through an internal control power transformer:
    a. VFD manufacturer shall provide protection for both the primary and secondary windings of the control power transformer.
3. This auxiliary power transformer shall be supplied to convert input medium voltage power to low voltage to provide power for control logic and auxiliary cooling motors.
4. VFD control circuits shall be 120 VAC single phase.
5. Manufacturer shall provide an internal control power transformer suitably rated to provide VFD required control power.

L. Protective devices/diagnostics:
1. Power component protection:
    a. VFD system shall include distribution class surge arrestors to protect the input transformer and VFD against voltage surges.
    b. VFD system shall include power fuses on the input to the converter rectifier devices to protect the secondary of the transformer from any potentially harmful fault currents:
        1) Alternative arrangements that involve coordinated protection with an input circuit breaker are not as desirable. If proposed, the VFD system manufacturer must include coordinating elements, including the circuit breaker itself, and must provide a detailed description.
2. Protective features and circuits:
    a. Controller shall include the following alarms and protective features:
        1) Static instantaneous over-current and over-voltage trip.
        2) Under-voltage and power loss protection.
        3) Over-temperature protection.
        4) Electronic motor inverse time overload protection.
        5) Responsive action to motor winding resistive temperature detectors, RTDs, 100-ohm platinum.
        6) When power is restored after a complete power outage, the VFD shall be capable of catching the motor while it is still spinning and restoring it to proper operating speed without the use of an encoder.
    b. VFD system shall be protected from damage due to the following, without requiring an output contactor:
        1) Single-phase fault or 3-phase short circuit on VFD system output terminals.
        2) Failure to commutate inverter thyristor due to severe overload or other conditions.
        3) Loss of input power due to opening of VFD input disconnect device or utility power failure during VFD operation.
        4) Loss of 1 phase of input power.
        5) Motor regeneration due to backspin or loss of VFD input power.

c. VFD shall be able to withstand the following fault conditions without damage to the power circuit components:
   1) Failure to connect a motor to the VFD output.
   2) VFD output open circuit that may occur during operation.
d. VFD shall include a customer selectable automatic restart feature:
   1) When enabled, the VFD shall automatically attempt to restart after a trip condition resulting from over-current, over-voltage, under-voltage, or over-temperature.

3. Motor protection relay:
   a. As specified in Section 26_13_05 - Protective Relays.

M. Diagnostics and fault recording:
1. Control logic section shall be fully digital and not require analog adjustment pots or fixed selector resistors.
2. Fault log data storage memory shall be stored in non-volatile memory.
3. VFD shall include a comprehensive microprocessor based digital diagnostic system which monitors its own control functions and displays faults and operating conditions.
4. A “FAULT LOG” shall record, store, display, and print upon demand, the following 50 most recent events:
   a. VFD mode (Auto/Manual).
   b. Date and time of day.
   c. Type of fault.
   d. Reset mode (Auto/Manual).
5. A “HISTORIC LOG” shall record, store, display and print upon demand, the following control variables at an adjustable time interval for the 50 intervals immediately preceding a fault trip and 100 intervals following such trip:
   a. VFD mode (Manual/Auto/Inhibited/Tripped, etc.).
   b. Speed demand.
   c. VFD output frequency.
   d. Demand (output) amps.
   e. Feedback (motor) amps.
   f. VFD output volts.
   g. Type of fault.
   h. Drive inhibit (On/Off).
   i. Fault log record shall be accessible via a RS232 serial link, as well as line by line on the keypad display.
6. A Windows-based graphical tool suite shall be supplied with the VFD:
   a. This graphical PC tool shall be able to plot and display up to 8 different VFD parameters and have the ability to freeze plotting and print hard-copy versions of the plots.
   b. It shall be capable of displaying at least 8 different VFD system parameters. Parameters displayed on the PC tool shall be synchronized with the standard keypad display.

N. Power bus and wiring:
1. Main power bus shall be high-conductivity copper and tin-plated for chemical and corrosion resistance and low losses:
   a. Bus shall be appropriately sized for the VFD continuous current rating and braced to withstand the mechanical forces caused by a momentary short

circuit current of a minimum of 40 kA or the actual calculated fault current level, whichever is greater, expected at the bus.
b. Connections shall be bolted or continuously welded.
c. Main grounding of the VFD system shall have a common loop consisting of 4/0 minimum copper cable placed in the enclosure base.
d. This cable shall loop the perimeter of the base and shall be attached to stainless steel grounding pads welded to the base in 2 locations, one at each end of the enclosure.

2. Control wiring shall be physically separated from the power wiring:
   a. Low and high voltage cables shall be physically isolated from each other.
   b. VFD system shall be pre-wired within the enclosure:
      1) Only ring type connectors are allowed, spade type connectors are not acceptable.
      2) No soldering shall be used in connection with any wiring.
   c. Wiring shall be adequately supported to avoid tension on conductors and terminations.
   d. Wiring shall be run in surface mounted conduit or wire-ways:
      1) Any section of wiring outside of conduit or wire-way shall be securely tied with cable ties at intervals not exceeding 6 inches.
      2) No cables shall be tied off to or in any way supported from power buses.
   e. Wherever wiring passes metal edges or through holes, suitable guards or grommets shall be provided to prevent cutting or chafing of the insulation.
3. Terminal blocks shall have at least 20 percent spares:
   a. No more than 2 wires shall be terminated on 1 terminal.
4. Wiring shall be tagged with permanent labels at each termination, junction box, and device:
   a. Labels shall correspond to the schematic and wiring diagrams.
5. Ground connection:
   a. Stainless steel grounding pads shall be provided in each power cubicle.
   b. A tin-plated copper ground bus shall be provided for grounding of control circuits.

O. Input power terminations:
1. Input and output power connections shall be made to isolated supported and plated bus strap connections.
2. Sufficient space shall be provided for termination connections from the top or the bottom of the VFD cubicle.
3. Space provisions shall be provided for application of standard stress cones, and provisions shall be provided for grounding of shielded cabling.

P. Input isolation:
1. Provide an air gap type input isolation switch to isolate the entire VFD from the power source.
2. Input isolation switch may be:
   a. Load break.
   b. Non-load break if interlocked with the VFD control system so that the VFD is stopped before opening of the isolation switch.
3. Design and construction of the switch and enclosure shall provide visual confirmation that the switch is open and that an air gap is present between the power source and the drive.

## 2.07 COMPONENTS

A. Data displays:
   1. A door-mounted flat panel display shall be furnished, capable of displaying the VFD operational status and drive parameters:
      a. Digital display must present diagnostic message and parameter values in plain English, engineering units when accessed, without the use of codes.
   2. As a minimum, the following door mounted digital indications shall be supplied:
      a. Speed in percent.
      b. Input current in amperes.
      c. Output current in amperes.
      d. Output frequency in hertz.
      e. Input voltage.
      f. Output voltage.
      g. Total 3-phase kilowatt output.
      h. Kilowatt hour meter.
      i. Elapsed time running meter.

B. User input/keypad:
   1. Door of each power unit shall include:
      a. Manual speed device.
      b. A mode selector marked “Manual/Automatic”.
      c. A “POWER ON” light.
      d. A VFD “FAULT” light.
      e. A VFD “RUNNING” light.
      f. Start pushbutton.
      g. Stop pushbutton.
      h. A Reset pushbutton.
   2. A door-mounted keypad with integral digital flat panel display shall be furnished, capable of controlling the VFD and setting drive parameters:
      a. Display must present diagnostic message and parameter values in standard engineering units when accessed, without the use of codes.
      b. Keypad shall allow the operator to enter exact numerical settings in standard engineering units.
      c. An English language user menu, rather than codes, shall be provided in software as a guide to parameter setting.
   3. Drive parameters shall be factory set in non-volatile EEPROM registers and re-settable in the field through the keypad:
      a. A minimum of 6 levels of password security shall be available to protect drive parameters from unauthorized personnel.
      b. EEPROM stored drive variables must be able to be transferred for programming of new or spare boards.
   4. Keypad module shall contain a “self-test” software program that can be activated to verify proper keypad operations.
   5. VFD system shall have the user selectable option of programming up to 3 speed avoidance bands.

C. Hard-wire communication:
   1. When indicated on the Drawings, additional analog input and output signals and additional digital inputs and outputs shall be provided.

D. Serial communication/protocols/modem or cable:
   1. VFD shall be capable of direct communication to an IBM or compatible computer for:
      a. Serial link setup of parameters.
      b. Fault diagnostics.
      c. Trending.
      d. Diagnostic log downloading.
   2. An RS-232 port shall be door-mounted for computer or printer interface.
   3. VFD parameters, fault log and diagnostic log shall be downloadable for hard copy printout via the RS-232 port and a standard serial printer.
   4. An Ethernet communications link shall be provided.

E. Printed circuit boards:
   1. Shall be new.
   2. Conformally coated for moisture and chemical resistance, in addition to any dielectric coating properties.

F. Input isolation transformer:
   1. VFD system is to be supplied with a drive isolation transformer to provide common mode voltage protection and phase shifting for 18 pulse or higher converter bridge:
      a. VFD systems utilizing input 3-phase alternating current line reactors which require motors equipped with special higher voltage rated insulation systems are not acceptable.
   2. Transformer design to be a rectifier grade isolation type with a K-Factor of 20 when applied to a SCR converter, in accordance with current EPRI recommendations and IEEE C57.12.01.
   3. If dry type transformers are required, they shall be rated for a maximum 115 degrees Celsius rise and minimum 220 degrees Celsius insulation with over-temperature protection:
      a. Transformers shall be OA rated and applied in a FA installation.
   4. If oil-filled type transformers are required:
      a. They shall have a maximum temperature rise of 55 degrees Celsius, and insulation rated for 155 degrees Celsius with:
         1) Over-temperature.
         2) Bucholtz.
         3) Sudden pressure protection.
      b. If the total oil capacity of the transformer exceeds 500 gallons, the oil sump and containment provisions shall be supplied as part of the VFD system.

G. Direct current link inductors:
   1. If required, shall be air core to prevent saturation.
   2. Separate inductors, split dual winding type, shall be provided in the positive and negative leg of the direct current link to minimize stray magnetic fields.
   3. Maximum temperature rise shall not exceed 115 degrees Celsius with minimum 220 degrees Celsius insulation and over-temperature protection.
   4. Inductors shall be integral to the VFD system lineup.

5. If it is not possible to integrate the inductors into the VFD system enclosure, the cabling and connecting must be entirely supplied and/or contracted by the VFD system manufacturer and approved by the Engineer.
6. Inductors shall meet the requirements of IEEE C57.16 and shall be designed to prevent saturation under maximum fault current conditions.

H. Direct current link capacitors:
1. Capacitors used in the converter direct current link shall be integral to the VFD system lineup.
2. Capacitors used in the converter direct current link shall contain discharge resistors and capable of reducing the residual charge to 50 volts or less within 5 minutes after the capacitor is disconnected from the source of supply.

## 2.08 ACCESSORIES

A. Input harmonic filters:
1. If harmonic filters are required to meet the specified input harmonic requirements, power factor requirements, stricter local requirements, or telephone interference factor restrictions, the VFD manufacturer must provide the active harmonic filter, upstream filter isolation, protection and protection coordination.
2. In as much as harmonic filters, even active harmonic filters, are power system dependent, the VFD supplier is responsible for maintaining and providing any required upgrades required for the first 10 years of operation at no cost to the Owner.
3. Components shall be integral to the VFD system lineup but isolated from other components, such that they can be disconnected from the power source and accessed for maintenance/repair while the VFD is in operation:
   a. If it is not possible to integrate the filters into the VFD system enclosure, the cabling and connecting must be entirely supplied and/or contracted by the VFD system manufacturer and approved by the Engineer.
4. Must be located on the primary side of the input isolation transformer and must be switchable with the VFD to prevent their remaining on the power line in the event of a VFD trip that could create a damaging leading power factor condition.
5. Complete filter must have independent protection for over-current, phase differential and ground fault.
6. Any inductors used shall be iron-core or air-core with a maximum temperature rise of 115 degrees Celsius with minimum 220 degrees Celsius insulation and over-temperature protection:
   a. Reactors shall be designed to prevent saturation under maximum fault current conditions.
   b. Reactors shall meet the requirements of IEEE C57.16.
7. Capacitors used in the harmonic filter banks shall met the requirements of IEEE 18 and IEEE 1036 for shunt power capacitors:
   a. Provided with a method of shorting the phases to ground once power has been removed and the capacitors have been discharged to a safe voltage level.
   b. Where oil-filled capacitors are required and the total volume of oil exceeds 500 gallons, the oil sump and containment provisions shall be supplied as part of the VFD system.

B. Output filters:
   1. If an output filter is required to meet the output harmonics requirements of this Section, or to meet any special requirements of the application, they must be fully incorporated into the VFD system design.
   2. Components shall be integral to the VFD system lineup:
      a. If it is not possible to integrate the output filters into the VFD system enclosure, the cabling and connecting must be entirely supplied and/or contracted by the VFD system manufacturer and approved by the Engineer.
   3. Any inductors used shall be iron core with a maximum temperature rise of 115 degrees Celsius with minimum 220 degrees Celsius insulation and overtemperature protection:
      a. Reactors shall be designed to prevent saturation under maximum fault current conditions. Reactors shall be in accordance with IEEE C57.16.
   4. Capacitors used in the harmonic filter banks shall be in accordance with IEEE 18 and IEEE 1036 for shunt power capacitors:
      a. Provided with a method of shorting the phases to ground once power has been removed and the capacitors have been discharged to a safe voltage level.
   5. Where potential exists for self-excitation between the output filter and the motor system, an output contactor rated, for both voltage and current, shall be provided by the VFD manufacturer as part of the VFD system delivery.

C. Lightning arresters:
   1. Heavy-duty distribution class MOV type surge arresters, for installation on the specified nominal voltage system.
   2. Provide brackets, wiring, and other hardware as necessary for cubicle mounting.
   3. Designed and manufactured in accordance with the latest edition of IEEE C62.11.

## 2.09 FABRICATION

A. Accessibility and configuration:
   1. Front access:
      a. VFD system shall be designed for front access only:
         1) Equipment that requires side or rear access is not acceptable.
   2. Power component accessibility:
      a. Components in the converter sections shall be designed for rack-out accessibility for ease of maintenance and to minimize repair downtime.
      b. Alternate access options must be described in the Submittals for the Owner’s review and evaluation.
   3. Voltage isolation:
      a. Low voltage components, circuits, and wiring shall be separated with physical barriers from any sources of medium voltage.
   4. Remote diagnostics:
      a. VFD system shall be provided with the capability for remote diagnostics via modem communication, Ethernet link, and DeviceNet.

5. Marking/labeling:
    a. Machine printed sleeve type wire marker tags or other acceptable means of permanent identification shall be applied to power and control wiring.
    b. Individual nameplates shall be provided for major components of the VFD system.
6. Mean time to repair (MTTR):
    a. VFD design must demonstrate an actual mean time to repair of less than 30 minutes, in the event of any power switching component failure.

B. Heat dissipation/cooling system:
1. Air-cooled:
    a. VFDs shall be provided with fan redundancy and automatic switchover in the event of a fan failure:
        1) If a fan fails, the system must automatically switch to the alternate fan and generate an alarm to notify operators of initial fan system failure.
    b. Drive must have ability to detect failed operation of the cooling system:
        1) Using temperature detectors as the only protection against loss of fan system is not acceptable.
    c. During normal operation, the system must periodically cycle between the 2 fan systems to “exercise” them:
        1) VFD system manufacturer shall provide heat dissipation data necessary to design auxiliary HVAC systems.

C. Enclosure:
1. VFD system components, including transformer, shall be mounted and wired by the VFD system manufacturer in a grounded enclosure:
    a. An outdoor pad-mounted mineral oil insulated input isolation transformer shall be allowed; however, the installation for said transformer shall be at no additional cost to the Owner.
2. Input filters, transformer, power conversion, output filters and auxiliary equipment enclosure sections shall be NEMA Type 12 Ventilated, IP-41 or better degree of protection, with gasketed doors.
3. VFD units shall have cleanable filter media covering air inlets:
    a. 100 percent washable.
    b. Constructed of a progressively structured, corrosion-free media.
    c. Filters shall be front replaceable for cleaning while the VFD is in operation without exposing maintenance personnel to any of the power components.
4. Microprocessor and control logic boards and their power supplies shall be housed in a sealed, non-ventilated NEMA Type 12 section, safely accessible without exposure to high voltages and without drive shutdown.
5. Low voltage wiring shall be fully isolated from medium voltage compartments by metal barriers.
6. Cabinets and doors shall be fabricated using heavy gauge steel, 12-gauge minimum, for sturdy construction and dimensional integrity to ensure long-term fit and function:
    a. Doors shall be gasketed to provide environmental protection and secure fits.

7. Enclosures must be designed to avoid harmonic and inductive heating effects:
    a. Must be designed to shield any outside equipment from interference, enclosing and shielding the complete system to eliminate any radio frequency interference in accordance with FCC Part 18 requirements and CE Mark standards.
    b. VFD system shall be labeled with the CE Mark.

D. Cabling:
1. VFD system wiring: Power, control, and protection shall be located internally within the VFD system enclosure.
2. Power wiring shall be isolated by voltage class.
3. Control and protection wiring shall be isolated from power wiring.

## 2.10 FINISHES

A. Cabinet color shall be the manufacturer's standard gray.

B. Paint procedures and materials shall be the VFD manufacturer's standard system designed and proven for resistance to chemical attack in environments consistent with:
1. Industrial powerhouse.
2. Water treatment.
3. Wastewater treatment.

## 2.11 SOURCE QUALITY CONTROL

A. Source Testing:
1. Witnessed, in-person:
    a. Number of Owner and Engineer representatives in person: 2.
2. Subassembly tests:
    a. Printed circuit boards shall be visually inspected and functionally tested:
        1) Boards must be tested individually before assembly.
        2) Each board shall be load and temperature cycled from no load to full load and from ambient to plus 60 degrees Celsius during a 48-hour burn-in test.
        3) Any boards that exhibit drift during the test must be replaced with boards that have successfully completed the burn-in without drift.
    b. Power assemblies shall be visually inspected and then HIPOT tested:
        1) Complete diagnostics and logic shall be tested.
        2) Complete power conversion circuit shall be thoroughly tested at 100 percent load for a minimum of 1 hour and then tested for 1 minute at momentary overload rating.
3. System level tests:
    a. Complete VFD shall be given preliminary checks, including verification of electrical connections, including ground connections, power and control wiring shall be resistance-checked point-to-point.
    b. E-prom and EE-prom shall be checked for correct revision level.
    c. Visual check shall be performed to verify:
        1) Degree of protection for cabinets.
        2) Input isolation is lockable in the off position.
        3) Marking of terminals and wiring.

4) Space availability for cable termination.
5) Accessibility of components and ease of maintenance and repair.

d. VFD system shall be fully checked against the approved Drawings for compliance and correct physical dimensions.
e. Power circuit and control circuits shall be HIPOT tested to ground.
f. Control voltage levels are to be checked and verified.
g. A no load test is to be performed on the system:
   1) Drive is to be connected to an unloaded motor and feedback signals shall be verified.
   2) Output voltage shall be calibrated.
   3) Logic and interlocks, including customer logic and instrumentation, shall be tested.
h. Drive shall be given a full power test at an ambient of 40 degrees Celsius and at rated current and rated voltage, simultaneously, for a minimum of 4 hours, or until all system temperatures stabilize, whichever is longer, on a dynamometer or reactor load:
   1) This test shall be performed as an integrated system, including:
      a) Supplied input switchgear.
      b) Input transformer.
      c) Input filter.
      d) Power section.
      e) Output filter.
   2) Perform the factory system test to verify that total system efficiency, power factor, and harmonic distortion limits are met as specified:
      a) Total system efficiency shall be measured using watt-meters or approved equivalent meters on both the input and the output of the complete system.
   3) System shall not be shipped unless specified performance criteria are met.

4. Furnish test reports and Manufacturer's Certificate of Source Testing. Include the following:
   a. Efficiency at rated power output and output frequency of 60 hertz.
   b. Power factor at 0 percent, 25 percent, 50 percent, 75 percent, and 100 percent speed.
   c. Harmonics at the input terminals of the VFD at 100 percent speed and 100 percent load:
      1) Voltage distortion: Measure individual harmonics up to and including the 50th harmonic and total harmonic distortion.
      2) Current distortion: Measure individual harmonics up to and including the 50th harmonic and total demand distortion.

## PART 3 EXECUTION

### 3.01 EXAMINATION (NOT USED)

### 3.02 PREPARATION (NOT USED)

## 3.03 INSTALLATION

A. Installation Verification:
   1. Furnish Manufacturer's Certificate of Installation Verification.

## 3.04 FIELD QUALITY CONTROL

A. Provide the services of the VFD manufacturer to conduct a harmonic study and verify compliance of field measurements for harmonic distortion differences at the PCC with and without VFDs operating:
   1. Verification of VFD input harmonic voltage and current distortion limits specified must be verified at rated speed and rated power as part of final startup and acceptance:
      a. A recording type Fluke, BMI, or equivalent harmonic analyzer displaying individual and total harmonic currents and voltages must be utilized.

## 3.05 OWNER TRAINING

A. Perform Owner Training as specified in Section 01_75_17 - Commissioning.

## 3.06 ADJUSTING

A. Make adjustments as necessary and recommended by the manufacturer, Engineer, or testing firm.

B. Provide the services of a qualified manufacturer's representative for start-up assistance:
   1. Inspection and field adjustment:
      a. Supervise equipment installation and confirm controls have been properly installed, aligned, adjusted, and readied for operation.
   2. Drive parameter and protection settings:
      a. Program protection settings provided by the VFD manufacturer and coordinated with the driven equipment supplier.
   3. Provide documentation of VFD settings, including, but not limited to:
      a. Minimum speed.
      b. Maximum speed.
      c. Skip speeds.
      d. Current limit.
      e. Acceleration time.
      f. Deceleration time.
      g. Carrier frequency.
      h. Motor nameplate information.
      i. All protection settings.

END OF SECTION

## SECTION 43_24_50.10

## VERTICAL TURBINE SHORT SETTING CENTRIFUGAL PUMPS

### PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Pump systems, including vertical turbine pumps with radial, mixed flow, or axial (propeller) type impellers and drivers as scheduled.

B. Tag numbers: As specified in the Pump Schedule.

### 1.02 REFERENCES

A. American Bearing Manufacturers Association (ABMA):
   1. 9 - Load Ratings and Fatigue Life for Ball Bearings.
   2. 11 - Load Ratings and Fatigue Life for Roller Bearings.

B. American Society of Mechanical Engineers (ASME):
   1. B16.1 - Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, and 250.
   2. B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24, Metric/Inch Standard.

C. American Water Works Association (AWWA):
   1. C205 - Standard for Cement-Mortar Protective Lining and Coating for Steel Water Pipe, 4 In. (100 mm) and Larger-Shop Applied.

D. ASTM International (ASTM):
   1. A48 - Standard Specification for Gray Iron Castings.
   2. A53 - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
   3. A108 - Standard Specification for Steel Bars, Carbon and Alloy, Cold-Finished.
   4. A276 - Standard Specification for Stainless Steel Bars and Shapes.
   5. A278 - Standard Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (350°C).
   6. A283 - Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates.
   7. A516- Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate-and Lower-Temperature Service.
   8. A582 - Standard Specification for Free-Machining Stainless Steel Bars.
   9. A743 - Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application.
   10. B30 - Standard Specification for Copper Alloys in Ingot Form.
   11. B505 - Standard Specification for Copper Alloy Continuous Castings.
   12. B584 - Standard Specification for Copper Alloy Sand Castings for General Applications.

13. F593 - Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
14. F594 - Standard Specification for Stainless Steel Nuts.

E. Hydraulic Institute (HI):
1. 9.1-9.5 - Pumps - General Guidelines for Types, Definitions, Application, Sound Measurement and Decontamination.
2. 14.1-14.2 - Rotodynamic Pumps for Nomenclature and Definitions.
3. 14.3 - Rotodynamic Pumps for Design and Application.
4. 14.4 - Rotodynamic Pumps for Installation Operation and Maintenance.
5. 14.6 - Rotodynamic Pumps for Hydraulic Performance Acceptance Tests.

## 1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
1. Allowable operating region (AOR): Region over which the service life of the pump is not seriously compromised by hydraulic loads, vibration, or flow separation where the pump's vibration, noise, and cavitation are within acceptable limits.
2. Preferred operating region (POR): Region over which the service life of the pump will not be significantly affected by hydraulic loads, vibration, or flow separation where the pump's vibration, noise, and cavitation are within acceptable limits.
3. Pump head (total dynamic head, TDH), flow capacity, pump efficiency, net positive suction head available (NPSHa), and net positive suction head required (NPSHr): As defined in HI 9.1-9.5, 14.1-14.2, 14.3, 14.4, and 14.6, and as modified in the Specifications.
a. Pump head and efficiency are evaluated at the outlet of the discharge head and include the net losses in the pump column and discharge head, and barrel/can, intake basket or strainer (when specified).
4. Suction head: Gauge pressure available at pump intake flange or bell in feet of fluid above atmospheric.
5. Tolerances: This Section and related sections contain tolerances that may be more stringent than HI standard tolerances. Where tolerances are not specified, HI 9.1-9.5, 14.1-14.2, 14.3, and 14.4 shall apply.

## 1.04 DELEGATED DESIGN

A. As specified in Section 01_35_73 - Delegated Design Procedures.

B. Rotordynamic analysis.

## 1.05 SUBMITTALS

A. Furnish Submittals as specified in Section 01_33_00 - Submittal Procedures.

B. Product Submittals:
1. As specified in Section 01_60_01 - Product Requirements.
2. Product data.

3. Pump curves:
    a. Shall represent the pump head and efficiency through the entire published curve from shut-off through the limits of the AOR. Pump curves that are limited to “bowl performance” are not acceptable.
    b. Clearly indicate limits of the POR and AOR on the full speed and variable speed curves.
4. Manufacturer’s instructions.
5. Calculations.
    a. Torsional analysis.
6. Schedules.
7. Furnish motor Submittals as specified in Section 26_05_10 – Medium Voltage Motors.

C. Quality Control Submittals:
1. Manufacturer’s representative qualifications.
2. Manufacturer’s Certificate of Source Testing as specified in Section 01_75_17 - Commissioning.
3. Manufacturer’s Certificate of Installation Verification as specified in Section 01_75_17 - Commissioning.
4. Manufacturer’s Certificate of Functional Compliance as specified in Section 01_75_17 - Commissioning.

D. Owner Training Submittals:
1. As specified in Section 01_75_17 - Commissioning.

E. Operation and maintenance manuals:
1. As specified in Section 01_78_24 - Operation and Maintenance Manuals.

## 1.06 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01_60_01 - Product Requirements, Section 46_05_10 - Common Work Results for Mechanical, and the manufacturer’s instructions.

## 1.07 PROJECT OR SITE CONDITIONS

A. As specified in Section 01_81_50 - Design Criteria.

## 1.08 WARRANTY

A. As specified in Section 01_78_36 - Warranties and Bonds.

## 1.09 MAINTENANCE

A. Spare parts:
1. Seal packing material: 1 set of each type supplied.
2. Line shaft rubber bearings: 1 set for each type pump.
3. Line shaft bronze bearings: 1 set for each type pump.
4. Impeller and bowl wear rings: 1 set for each type of pump.
5. Motor/gear thrust bearing set: 1 for each type of pump.
6. Motor radial bearing set: 1 for each size of motor (if specified).

7. Pump impeller/bowl assembly: 1 of each type supplied.
8. Line shaft: 1 length of each size and type.

B. Special tools: Deliver 1 set for each furnished pump type and size needed to assemble and disassemble pump system.

## PART 2 PRODUCTS

### 2.01 MANUFACTURERS

A. One of the following or equal:
1. Flowserve; model as scheduled.
2. Sulzer/Johnston Pumps; similar to scheduled model.
3. ITT; similar to scheduled model.

### 2.02 DESIGN AND PERFORMANCE CRITERIA

A. Components: Pumps, drivers, motors, variable frequency drives (VFDs), and drive arrangements as specified or as scheduled with shafts, columns, barrels, intermediate bearings, seals or packing, couplings, base plates, guards, supports, taps, lifting eyes, stands, and other items as required for a complete and operational system.

B. Design requirements:
1. Pump performance characteristics:
a. As specified in the Pump Schedule.
b. Rotordynamic analysis level: As scheduled and as specified in Section 46_05_10 - Common Work Results for Mechanical Equipment.
1) Vibration analysis expert: Provide when scheduled.
c. Required conditions (flow/head) shall be within the pump manufacturer's Allowable Operating Region (AOR).
d. Performance tolerances shall be the same as the test tolerances specified in Section 46_05_94 - Mechanical Equipment Testing.
e. Pump curve shall be continuously rising throughout the design conditions listed in the Pump Schedule.
2. Motor characteristics: As specified in the Pump Schedule.

C. Product requirements: As specified in Section 01_60_01 - Product Requirements and Section 46_05_10 - Common Work Results for Mechanical Equipment.

### 2.03 MATERIALS

A. General:
1. Pump Schedule materials: As specified in this Section.
2. Drinking water pumps: Provide materials as specified in Section 46_05_10 - Common Work Results for Mechanical Equipment.

B. Cast iron: ASTM A48, Class 30 minimum.

C. Nickel cast iron: ASTM A48, minimum Class 30, cast iron with 3 percent nickel.

D. Gray iron casting: ASTM A278, Class 30.

E. Iron-chromium alloy: ASTM A743, Grade CA40; ASTM A276, Type 420 Stainless Steel may be substituted; Brinell hardness number of 350 to 380.

F. Lead-free bronze, except for bearings that require lead for lubricity: ASTM B584.

G. Leaded tin bronze: ASTM B505, Alloy C92700.

H. Bronze or high lead tin bronze: ASTM B584, Alloy 93800.

I. Leaded red brass: ASTM B584, Alloy C83600, leaded red brass.

J. Type 416 stainless: ASTM A582, Type 416 stainless steel.

K. Neoprene: Polychloroprene rubber.

L. Steel: ASTM A283, Grade D or ASTM A516, Grade 70.

M. Steel pipe: ASTM A53, Grade B.

N. Aluminum bronze meeting the requirements of Section 46_05_10 - Common Work Results for Mechanical Equipment.

O. Lead-free aluminum bronze: ASTM B30.

## 2.04 PUMP CONSTRUCTION

A. Type: Industrial, heavy duty, vertical turbine, centrifugal type pumps meeting performance requirements and features as scheduled and as specified.

B. Discharge flange: ASME B16.1 or ASME B16.5 drilled; rated for 1.2 times the pump shutoff head at 100 degrees Fahrenheit.

C. Discharge nozzles: Provide 1/2-inch NPT taps for pressure gauges; Contractor to install nipple and gauge with block valve.

D. Bearings:
   1. Design driver/motor bearings to support the line shaft assembly and rated for ABMA L10 life of 40,000 hours at Design Rated Point flow and head in accordance with ABMA 9 or ABMA 11.
   2. Design motor to withstand continuous duty full load thrust and momentary up thrust that may occur during pump on/off or other operations.

E. Fasteners: Type 316 stainless steel in accordance with ASTM F593 or ASTM F594.

## 2.05 PUMP SUCTION ASSEMBLY

A. Provide suction bell. Provide anti-vortex baffles and strainer when scheduled.

B. Design suction bells and provide strainers and anti-vortex baffles to minimize solids plugging and vortexing. Screens shall have a flow area at least 4 times the suction pipe area.

C. Materials:
   1. Pump suction bell: As scheduled.
   2. Anti-vortex baffles: Same material as scheduled for pump suction bell.
   3. Pump suction bell bearing: As scheduled.
   4. Pump suction strainer: When strainer scheduled, provide Type 316 stainless steel.

## 2.06 PUMP IMPELLER BOWL ASSEMBLIES

A. Pump impeller assembly:
   1. Type: As scheduled.
   2. Maximum number of vanes: As scheduled.
   3. Number of stages: As scheduled.
   4. Required balance: As specified in Section 46_05_10 - Common Work Results for Mechanical Equipment to meet vibration criteria as specified in Section 46_05_94 - Mechanical Equipment Testing.
   5. Method of securing impellers to shafts: As described in this Section or by other methods acceptable to the Engineer.
      a. Attach impellers to the shaft with stainless steel tapered collets for nominal bowl model sizes 16 inches or smaller.
      b. For nominal bowl model sizes greater than 16 inches, attach impeller with stainless steel split ring and key.
      c. Provide any special tools required for removal and installation of pump impellers.
   6. Provisions for adjustment of axial clearance: Make such adjustment through use of motor adjusting nut or adjustable coupling.
   7. Impeller thrust: When appropriate for the specified impeller type, provide hydraulically balanced impeller to minimize down thrust.

B. Intermediate and discharge impeller cases:
   1. Material: As scheduled.
   2. Attached with bolting.

C. Pump impeller bowl bearings: Provide bearing for each impeller; material as scheduled.

D. Diffusion vanes: Provide vanes cast into bowl.

E. Suction bowl bearings:
   1. Provide bronze sleeved bearings with self-contained lubrication system filled with graphite type non-soluble grease when grease lubrication scheduled; provide bearing with sand cap.

F. Design with smooth water passages to reduce clogging by stringy or fibrous materials on impellers or shafting.

G. Design replaceable wear rings for both the bowl and impeller on each impeller bowl.

H. Design capable of passing solids with a sphere size as scheduled or larger.

I. Design impellers capable of working on pumps that may be abnormally started against closed manual valve or normally against a closed pump control valve.

## 2.07 LINE SHAFTS

A. Provide line shaft type and lubrication type as scheduled and as specified in this Section.

B. Open line shaft, product lubricated:
   1. Shaft and couplings:
      a. Provide keyed shaft type mechanical couplings with key or set screw locking of shaft couplings.
         1) Threaded shaft connections are not allowed.
   2. Bearings and bearing retainers: Provide bearings and retainers spaced as scheduled, but not to exceed 10 feet; provide at least 1 bearing for each line shaft length; provide grease fitting for top bearing extended to outside any guards when grease lubrication specified.
   3. Materials:
      a. Shaft and couplings: As scheduled; where hard faced steel shaft is specified, hard face at sleeve bearings to 550 Brinell minimum.
      b. Bearings and bearing retainers: As scheduled; when not scheduled, Neoprene rubber bearings with retainers shall be same material as the column.

C. Design strength: Able to withstand minimum 1.5 times maximum operating torque and other loads.

D. Resonant frequency: As specified in Section 46_05_10 - Common Work Results for Mechanical Equipment and Section 46_05_94 - Mechanical Equipment Testing.

E. Sleeves: Provide shafting with Type 316 stainless steel sleeve or hardened sleeves where shafts pass through bearings or stuffing boxes as scheduled; Brinell 550 or higher for hardened shaft; when the specified mechanical seals cannot be installed on a hardened shaft, hardened shafts are not required in the area of the mechanical seal.

F. Design pump line shafting in interchangeable lengths as scheduled, but not to exceed 10 feet; shaft lengths to match scheduled pump column lengths.

G. Coupling strength: Design driver to pump line shaft coupling of sufficient length and strength to maintain line shaft alignment.

H. Adjustment:
   1. Design a means to adjust shaft position to adjust impeller position.
   2. For motor driven units with hollow shafts, an adjusting nut will be provided at the top of the motor shaft.

## 2.08 PUMP COLUMN PIPE

A. Thickness and material as scheduled.

B. Head connection: Design with flanged and bolted connection to discharge head and flanged and bolted connection to impeller assembly to permit removal of impeller bowl assembly without disturbing the column or discharge connections.

C. Design working pressure: Design to withstand a design working pressure not less than 1.20 times the maximum shutoff total dynamic head with the maximum diameter impeller at the maximum operating speed plus the maximum suction static head.

D. Pressure test: Design to withstand a 5-minute hydrostatic test pressure not less than 1.5 times the design working pressure; perform test at source.

E. Lengths and connections: Design with maximum 10-foot length, or less if scheduled, interchangeable column sections with flanged or threaded with registered fit screwed connections as scheduled.

F. Diameter: Design column inside diameter for no more than 4 feet of fluid friction loss per 100 feet of column length.

## 2.09 PUMP DISCHARGE HEAD ASSEMBLY

A. Design the discharge head for above or base discharge as scheduled.

B. Design the discharge vertical to horizontal flow transition as a smooth pipe elbow or from a minimum of 3 pipe pieces mitered to form the elbow.

C. Design discharge head to mate with the driver as scheduled.

D. Head and base plate construction: Sufficient strength, weight, and thickness to provide accurate alignment, prevent excessive deflection and support the drive motor.

E. Stuffing box and seal:
   1. Design the discharge head with a stuffing box to accommodate packing or mechanical seals as scheduled.
   2. Shaft seal type: As scheduled and as specified in Section 46_05_10 - Common Work Results for Mechanical Equipment.
      a. Packing: When packing scheduled, provide stuffing box arranged for packing (sized for bronze lantern ring and 6 packing rings minimum); provide hollow shaft motor with top adjusting nut.
   3. Drain: Minimum 3/4-inch size, for pump stuffing box leakage, together with drain line to the pump can or wet well, or to the nearest equipment drain as indicated on the Drawings.

F. Discharge vent: Provide 3/4-inch NPT threaded high point vent on discharge; Contractor to install pipe nipple with threaded ball valve in vent.

G. Materials: As scheduled; when not scheduled, provide:
   1. Pump discharge head/driver stand: Steel, ASTM A283, Grade B and/or ASTM A53, Grade B; or cast iron, ASTM A48, Class 30 minimum.
   2. Pump discharge head sleeve bearing: Bronze.
   3. Stuffing box and seal: Container and gland, cast iron, ASTM A48, Class 30 minimum; Neoprene top shaft seal.

## 2.10 EQUIPMENT GUARDS

A. Provide equipment safety guards as specified in Section 46_05_10 - Common Work Results for Mechanical Equipment.

## 2.11 DRIVERS

A. Horsepower:
   1. As scheduled.

B. Motors: Provide motors as specified in Section 26_05_10 - Medium Voltage Motors, and as specified in this Section:
   1. RPM: As scheduled.
   2. Enclosure: As scheduled.
   3. Electrical characteristics: As scheduled.
   4. Efficiency, service factor, insulation, and other motor characteristics: As specified in Section 26_05_10 - Medium Voltage Motors.
   5. Motor accessories: As specified in Section Section 26_05_10 - Medium Voltage Motors and in this Section.
   6. Coordinate motors with the variable frequency drive (VFD) manufacturer to ensure compatibility between the motor and VFD.

C. VFDs: As scheduled and as specified in Section 26_18_42 – Medium Voltage Variable Frequency Drive.

D. Other drivers: As scheduled and as specified in sections listed in the Schedule.

E. Non-reverse ratchets: When scheduled, provide driver with non-reverse ratchets or pin mechanism to prevent reverse rotation of the pump and driver in the event of discharge valve failure.

## 2.12 SUPPORTS

A. Strength: Design pump discharge head and driver (motor or engine) supports to withstand a minimum of 1.5 times the maximum imposed operating loads or the imposed seismic loads, whichever is greater.

B. Resonant frequency: Design supports in conjunction with the pump, shafting, drivers, bearings, and other components to avoid natural resonant frequencies, either torsional, radial, or axial as specified in Section 46_05_94 - Mechanical Equipment Testing.

C. Coordinate pump and drive system supports with the foundation designs as indicated on the Drawings.

## 2.13 SOURCE QUALITY CONTROL

A. Source Testing (Factory Acceptance Tests):
   1. As specified in Section 01_75_17 - Commissioning.
   2. Witnessed, in-person.
      a. Number of Owner and Engineer representatives in person: 1.
   3. Test as specified in Section 46_05_94 - Mechanical Equipment Testing and the Pump Schedule.
   4. Pump casing: Hydrostatic pressure tests if specified in this Section.
   5. Furnish test reports and the Manufacturer's Certificate of Source Testing.

# PART 3 EXECUTION

## 3.01 PREPARATION

A. Not Used.

## 3.02 INSTALLATION

A. Furnish Manufacturer's Certificate of Installation Verification.

## 3.03 FIELD QUALITY CONTROL

A. Functional Testing:
   1. Furnish test reports and the Manufacturer's Certificate of Functional Compliance.

## 3.04 OWNER TRAINING

A. Perform Owner Training as specified in Section 01_75_17 - Commissioning.
   1. Number of sessions:
      a. Operations: 2.
      b. Maintenance: 2.

## 3.05 PUMP SCHEDULE

| Tag Numbers | PMP-305 and PMP-306 | PMP-302 and PMP-303 |
|---|---|---|
| **General Characteristics:** | | |
| Application | Raw Water | Raw Water |
| Service | Raw Water | Raw Water |
| Quantity | 2 | 2 |
| First Named Manufacturer's Model Number | 34EKL | 25EKL |
| Maximum Noise, dBA at 3 feet | 85 | 85 |
| Minimum Pumped Fluid Degrees Fahrenheit | 33 | 33 |
| Normal Pumped Fluid Degrees Fahrenheit | 60 | 60 |

| Tag Numbers | PMP-305 and PMP-306 | PMP-302 and PMP-303 |
|---|---|---|
| Maximum Pumped Fluid Degrees Fahrenheit | 100 | 100 |
| Rotordynamic Analysis Level | 2 | 2 |
| Vibration Analysis Expert | Required | Required |
| **Pump Characteristics:** | | |
| Number of Stages | 3 | 3 |
| Impeller Type | Enclosed | Enclosed |
| Impeller, Maximum Number of Vanes | Per manufacturer | Per manufacturer |
| Pass Minimum Sphere Size, Inch | 2 | 2 |
| Pump Impeller Bowl Bearing Lubrication | Product | Product |
| Shaft Seal Type | Type 1 | Type 1 |
| Suction Bowl Bearing Lubrication | Product | Product |
| Suction Strainer | NA | NA |
| Anti-Vortex Baffle | Required | Required |
| Line Shaft Type | Open | Open |
| Minimum Line Shaft Bearing Spacing, Feet | 10 | 10 |
| Line Shaft Lubrication | Product | Product |
| Column Connection Type | Flanged | Flanged |
| Column Thickness | Min. Sch 40 | Min. Sch 40 |
| Maximum Column Section Lengths, Feet | 10 | 10 |
| Pump Barrel or Can | None | None |
| Discharge Arrangement | Above | Above |
| Motor Coupling Type | Spacer | Spacer |
| Speed Control | Variable Frequency Drive | Variable Frequency Drive |
| Maximum Pump rpm | 1200 | 1200 |
| Minimum Pump rpm | 550 | 550 |
| **Rated Design Point (at Maximum Revolutions per Minute):** | | |
| Flow, gpm | 15,000 | 6,400 |
| Head, Feet | 635 | 260 |
| Minimum Efficiency, Percent | 78 | 78 |
| **Required Condition 2 (at Maximum Revolutions per Minute):** | | |
| Flow, gpm | 11,000 | 3,600 |
| Head Range, Feet | 730 to 790 | 300 to 340 |
| Minimum Efficiency, Percent | 75 | 48 |

| Tag Numbers | PMP-305 and PMP-306 | PMP-302 and PMP-303 |
|---|---|---|
| **Required Condition 3 (at Maximum Revolutions per Minute):** | | |
| Flow Range, gpm | 18,000 to 19,000 | 7,000 to 8,000 |
| Head, Feet | 479 | 208 |
| Minimum Efficiency, Percent | 40 | 40 |
| **Required Condition 4 (at Reduced Revolutions per Minute):** | | |
| Flow, gpm | 5615 | 1445 |
| Head, Feet | 188 | 84 |
| Minimum Efficiency, Percent | 76 | 57 |
| **Other Conditions:** | | |
| Maximum Shut Off Head, Feet | 1,042 | 494 |
| Maximum NPSHr at every Specified Flow, Feet | 34 | 18 |
| Minimum NPSHa at every Specified Flow, Feet | 34 | 34 |
| Minimum Suction Static Head, Feet | 5 | 5 |
| Maximum Suction Static Head, Feet | 30 | 30 |
| **Pump Materials:** | | |
| Suction Bell | Cast Iron | Cast Iron |
| Suction Bell Bearing | Bronze | Bronze |
| Impeller Cases | Cast Iron or 316 Stainless Steel | Cast Iron or 316 Stainless Steel |
| Impeller | Bronze | Bronze |
| Impeller Bearing | Bronze | Bronze |
| Impeller Shaft Key | Stainless Steel | Stainless Steel |
| Line Shaft and Coupling | Type 416 Stainless Steel or K-Monel | Type 416 Stainless Steel or K-Monel |
| Line Shaft Bearings | Bronze | Bronze |
| Shaft Enclosing Tube | N/A | N/A |
| Shaft Sleeve | Hardened | Hardened |
| Column Material and Thickness, Inch or Schedule | Steel Pipe, 0.25 min | Steel Pipe, 0.25 min |
| Can Material and Thickness, Inch or Schedule | N/A | N/A |
| Can Lining | N/A | N/A |
| Can Coating | N/A | N/A |
| Discharge Head/Driver Stand | Steel | Steel |

| Tag Numbers | PMP-305 and PMP-306 | PMP-302 and PMP-303 |
|---|---|---|
| Discharge Head Bearing | Bronze | Bronze |
| Discharge Stuffing Box | Steel | Steel |
| **Driver Characteristics:** | | |
| Driver Type | Motor | Motor |
| Drive Arrangement | Vertical, Coupled | Vertical, Coupled |
| Non-Reverse Ratchets | Required | Required |
| Minimum Driver Horsepower | 3000 | 600 |
| Maximum Driver rpm | 1200 | 1200 |
| **Motor Characteristics (when motor is driver type):** | | |
| Inverter Duty Rated | Yes | Yes |
| Motor Voltage/Phases/hertz | 4160/3/60 | 4160/3/60 |
| Enclosure Type | WP-1 | TEFC |
| **Source Testing:** | | |
| Performance Test Level | 2 | 2 |
| Vibration Test Level | 2 | 2 |
| Noise Test Level | 2 | 2 |
| **Functional Testing:** | | |
| Performance Test Level | 2 | 2 |
| Vibration Test Level | 2 | 2 |
| Noise Test Level | 2 | 2 |

END OF SECTION

## SECTION 46_05_10

## COMMON WORK RESULTS FOR MECHANICAL EQUIPMENT

# PART 1 GENERAL

## 1.01 SUMMARY

A. Section includes:
   1. Mechanical equipment requirements for:
      a. Basic design and performance criteria.
      b. Prescriptive requirements for common components.
      c. Installation requirements.

## 1.02 REFERENCES

A. American Bearing Manufacturers Association (ABMA):
   1. 9 - Load Ratings and Fatigue Life for Ball Bearings.
   2. 11 - Load Ratings and Fatigue Life for Roller Bearings.

B. American Gear Manufacturers Association (AGMA) Standards.

C. American Petroleum Institute (API):
   1. 682 - Pumps—Shaft Sealing Systems for Centrifugal and Rotary Pumps.

D. ASTM International (ASTM):
   1. A193 - Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications.
   2. A194 - Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.
   3. A320 - Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service.
   4. F593 - Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
   5. F594 - Standard Specification for Stainless Steel Nuts.

E. Hydraulic Institute (HI):
   1. 9.6.8 - Guideline for Dynamics of Pumping Machinery.

F. International Concrete Repair Institute (ICRI):
   1. Guideline No. 310.2R, Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair.

G. International Organization for Standardization (ISO):
   1. 21940 - Mechanical Vibration - Rotor Balancing - Part 1: Introduction.

H. National Electrical Manufacturers Association (NEMA):
   1. MG-1 - Motors and Generators.

I. Society for Protective Coatings (SSPC):
   1. SP 1 - Solvent Cleaning.

## 1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Definitions used in this specification and equipment Submittals for terms related to rotor-dynamic pumps shall be in accordance with HI 9.6.8, Appendix A, as clarified below.
   2. These definitions shall be applied to equipment other than pumps, unless otherwise specified in Technical Sections.
   3. Resonant frequency:
      a. Frequency of a periodic excitation force that is close to the natural frequencies of an object. Also known as critical frequency, critical speed, or resonant speed.
      b. An undamped resonant frequency within the separation margin is always considered harmful under Level 1 analysis.
      c. A resonant frequency that occurs within a separation margin of 15 percent above or below the operating speed range and has a log decrement greater than +0.3 is considered harmful under Level 2 and Level 3 analysis.
   4. Rotordynamic analysis level:
      a. Level of detail required for rotordynamic analysis is indicated in the Technical Sections schedules as None (no analysis required), Analysis Level 1, Analysis Level 2, or Analysis Level 3, which correlate to increasing levels of required detailed equipment design analysis. Analysis Levels 1, 2, and 3 are based on HI 9.6.8.
      b. Where these specifications differ from HI the more stringent shall apply.
   5. Separation margin:
      a. Span of operating speeds within which interference between excitation orders and resonant frequencies indicate the possibility of harmful vibrations.
      b. Separation margin for a specific application extends 15 percent above and 15 percent below the span of operating speed required for the specified performance conditions.

## 1.04 ADMINISTRATIVE REQUIREMENTS

## 1.05 SUBMITTALS

A. Items in this Section are components of equipment or systems specified in other Sections.
   1. Include data for this Section’s components with the equipment or system Submittal.

## PART 2 PRODUCTS

### 2.01 DESIGN AND PERFORMANCE CRITERIA

A. General:
   1. Equipment manufacturer's responsibility extends to selection and mounting of gear drive units, motors or other prime movers, accessories, and auxiliaries to provide a complete, operable unit.
   2. Manufacturer shall analyze rubber-bearing vertical-column pumps and equipment identified as non-reversing in the Technical Sections for reverse rotation and provide non reversing motor ratchets.
   3. Equipment that prevents reverse rotation shall be capable of both:
      a. Handling 150 percent of the maximum torque at maximum operating speed.
      b. 150 percent of torque that will be generated in reverse direction due to equipment shutoff head as calculated by the manufacturer.
   4. Motor shall be designed to run safely in the reverse direction at up to 140 percent times the reverse runaway speed under shutoff head conditions.

B. Rotordynamic analysis and vibration testing:
   1. Submit information for the rotordynamic analysis level specified for each piece of equipment as shown in the Technical Sections prior to manufacture of the equipment.
   2. Rotordynamic analysis shall be performed on "like-new" and "as-worn" conditions, representing conditions when first installed and conditions when parts wear to the manufacturer's maximum allowable operating tolerances.
      a. Conditions assumed for the "as-worn" condition shall be 2 times the "like-new" tolerances unless specified otherwise.
   3. Rotordynamic analysis criteria:
      a. Torsional excitation forcing function magnitudes shall be no less than 1 percent of the maximum transmitted torque at given speed.
      b. Motor mass elastic information in accordance with NEMA MG-1 shall be obtained from the original equipment manufacturer and included in the analysis. Motors shall be precision balanced to ISO 21940 Grade G2.5.
      c. Bearings:
         1) At maximum bearing loads an L-10 life of 100,000 hours in accordance with ABMA 9-11 to be proven.
   4. Submit factory and field testing requirements as specified in the Technical Sections and specified in Section 46_05_94 - Mechanical Equipment Testing after manufacture and installation respectively.
   5. Repair, replace, and modify equipment exhibiting vibration performance that does not meet criteria specified in this Section at no additional cost to the Owner.
      a. Acceptable remedies include adjustments to equipment component geometry, materials, energy absorbing couplings, etc.
      b. Locking out speed interval(s) within equipment specified operating range is unacceptable.
   6. Vibration analysis expert:
      a. Provide when specified in the equipment Technical Sections.
         1) Must be a 3rd party, unaffiliated with the equipment vendor or Contractor.

b. Analysis shall be provided by one of the following or equal:
    1) Engineering Dynamics Inc. (EDI, Texas).
    2) Mechanical Solutions, Inc. (MSI, New Jersey).
c. Analysis shall be:
    1) Stamped by a registered professional mechanical engineer.
    2) Verified in-situ by the vibration analysis expert, including certification that installation conforms to field conditions assumed in the reports.
    3) Verified in-situ by the vibration analysis expert, including witness of at least 1 field vibration test, and certification that vibration measurements corroborate the rotordynamic analysis.
    4) Supplemented with additional field investigation and analysis should conditions during field vibration testing activity indicate non-compliance with these specifications; supplemental field investigation and analysis shall indicate remedies to comply with the specifications and shall be stamped by a registered professional mechanical engineer.

7. Rotordynamic Analysis Level 1:
    a. Before the equipment is released for manufacture it shall be determined that the equipment/motor structures do not have any harmful resonant frequencies in the lateral and torsional modes. Representative analysis results for identical equipment may be submitted.
    b. Calculate rotor lateral and torsional and equipment structural components' lateral frequencies with a spreadsheet calculation or finite element analysis software.
        1) Equipment structure lateral frequency shall include the motor.
        2) Speed changing drive systems (belt, gear) effects on rotational inertia and stiffness shall be incorporated.
    c. Determine the equipment system components (rotor and structure) resonant frequencies.
    d. An intersection of an equipment component resonant frequency with the 1x run speed excitation order that occurs within separation margin is unacceptable.
8. Rotordynamic Analysis Level 2:
    a. Before the equipment and motor are released for manufacture it shall be determined that the equipment/motor structures do not have any harmful critical speeds in the lateral and torsional modes.
    b. Calculate rotor lateral and torsional and structure lateral frequencies with finite element analysis software.
        1) Equipment structure lateral frequency shall include the motor.
        2) Speed changing drive systems (belt, gear) effects on rotational inertia and stiffness shall be incorporated.
        3) Rotational inertia of water within the impeller, in the wet well, and inside the equipment structure, e.g., the column of a vertical pump, shall be included in the calculation at both the high level and low level conditions.
    c. Potentially harmful critical speeds shall be investigated further with a forced, damped analysis to determine component stresses do not exceed material properties.

d. Forced damped analysis:
    1) Forced lateral analysis shall include forcing function magnitudes at least 10 percent of rotor disc weight at each disc position and hydraulic imbalance at 5 operating conditions spaced equally over the equipment operating range. If synchronous motors are used ensure that the rotor analysis includes startup, shutdown, and motor control transients.
    2) Forced torsional analysis shall include not less than 1 percent of the maximum permitted torque at any given speed. Damping shall be 1 percent of critical at all shaft elements.
    3) Equipment rotor total stress (steady-state and alternating torque components plus lateral-bending stresses) shall not exceed:
        a) Constant torque: Total stress limited to 30 percent of the material fatigue limit and to a maximum of 18 percent of ultimate tensile strength.
        b) Variable torque (including variable speed equipment): Total stress limited to 50 percent of the material fatigue limit and to a maximum of 4 percent of the material ultimate tensile strength.
        c) Submit documentation of material fatigue limit.
e. Report Submittals:
    1) Confirmation of compliance with this Section, or detailed exceptions taken.
    2) Software used for analysis.
    3) Results with interpretation.
    4) Preparer's professional engineering stamp and seal.
    5) Input data, including component properties, materials and connectivity to other components.
    6) Schematic diagram of model mode shapes, nodes and elements.
    7) Bearing stiffness and damping properties, impeller/diffuser interaction coefficients, and seal dynamic properties.
    8) Campbell diagrams showing the system natural frequencies, excitation orders, and operating speed range for both lateral and torsional analysis.
        a) Include equipment operating range; excitation lines at 1x, 2x run speed, and vane pass (or equivalent); and critical speeds associated with equipment system components, including the rotor, each major equipment structural component and the motor.
    9) Forced, damped analysis indicating acceptable material stress limits are maintained at interference points shown on the Campbell diagram.

9. Rotordynamic Analysis Level 3:
    a. Before the equipment and motor are released for manufacture it shall be determined that the equipment/motor structures do not have any harmful critical speeds in the lateral and torsional modes.
    b. Calculate rotor lateral and torsional and structure lateral frequencies with finite element analysis software.
        1) Equipment structure lateral frequency shall include the motor.

2) Speed changing drive systems (belt, gear) effects on rotational inertia and stiffness shall be incorporated.
3) Rotational inertia of water within the impeller, in the wet well, and inside the equipment structure, e.g., the column of a vertical pump, shall be included in the calculation at both the high level and low level conditions.

c. Potentially harmful critical speeds shall be investigated further with a forced, damped analysis to determine component stresses do not exceed material properties.

d. Forced damped analysis:
1) Forced lateral analysis shall include forcing function magnitudes at least 10 percent of rotor disc weight at each disc position and hydraulic imbalance at 5 operating conditions spaced equally over the equipment operating range. If synchronous motors are used ensure that the rotor analysis includes startup, shutdown, and motor control transients.
2) Forced torsional analysis shall include 1 percent of the maximum permitted torque at any given speed. Damping shall be 1 percent of critical at all shaft elements.
3) Equipment rotor total stress (steady-state and alternating torque components plus lateral-bending stresses) shall not exceed:
a) Constant torque: Total stress limited to 30 percent of the material fatigue limit and to a maximum of 18 percent of ultimate tensile strength.
b) Variable torque (including variable speed equipment): Total stress limited to 50 percent of the material fatigue limit and to a maximum of 4 percent of the material ultimate tensile strength.
c) Submit documentation of material fatigue limit.

e. Report Submittals:
1) Report 1: Executive Summary, including:
a) Confirmation of compliance with this Section, or detailed exceptions taken.
b) Software used for analysis.
c) Results with interpretation.
d) Preparer's professional engineering stamp and seal.
e) Campbell diagrams showing the system natural frequencies, excitation orders, and operating speed range for both lateral and torsional analysis.
(1) Include equipment operating range; excitation lines at 1x, 2x run speed, vane pass (or equivalent), line- and twice-line frequency, motor-pole frequency, torsional harmonics from reciprocating drivers (including up to 6 times operating speed), control pulse frequencies induced by variable frequency drives (VFDs) (with certification from VFD manufacturer of frequencies up to 24 times motor running speed), any torque harmonic greater than 1 percent of steady torque at primary excitation, and synchronous motor requirements; and critical speeds associated with equipment system components, including the rotor and each major equipment structural component.

f) Report 1 shall not include detailed analysis elements listed for Submittal under Report 2 below, Submittal of full analysis details in Report 1 is unacceptable.
g) Following Submittal of Report 1, submit Report 2: Detailed Analysis, including responses to comments made on Report 1: Rotor-dynamic Executive Summary.

2) Report 2: Rotor-dynamic detailed analysis, including:
a) Input data, including component properties, materials and connectivity to other components.
b) Schematic diagram of model mode shapes, nodes and elements.
c) Bearing stiffness and damping properties, impeller/diffuser interaction coefficients, and seal dynamic properties.
d) Forced, damped analysis indicating acceptable material stress limits are maintained at interference points shown on the Campbell diagram.
e) Synchronous motor information, including time-integration study results showing transient peak stresses at startup, shutdown and motor control transient events. Provide tomographic diagrams, including root and keyway stress concentration locations and the corresponding speeds that result in reported peak stresses.

## 2.02 POWER TRANSMISSION SYSTEMS

A. V-belts, sheaves, shaft couplings, chains, sprockets, mechanical variable-speed drives, VFDs, gear reducers, open and enclosed gearing, clutches, brakes, intermediate shafting, intermediate bearings, and U-joints:
1. Rated for 24 hour-a-day continuous service, or for intermittent service with frequent stops-and-starts, whichever is most severe.
2. Sized with a service factor of 1.5 or greater:
a. Apply service factor to nameplate horsepower and torque of prime source of power and not to actual equipment loading.
b. Apply service factors in accordance with AGMA, or as specified in the Technical Sections.

## 2.03 BEARINGS

A. Oil or grease lubricated, ball or roller antifriction type, of standard manufacture.
1. Design lubrication system based on the equipment location to operate in the temperatures as specified in Section 01_81_50 - Design Criteria.
a. To safely start after being shut off for 24 hours and operate safely:
1) Suitable for the outdoor winter temperature as specified in Section 01_81_50 - Design Criteria.

B. Oil-lubricated:
1. Provide either pressure lubricating system or separate oil reservoir splash-type system as specified in the Technical Section.
2. Design system to safely absorb heat energy generated in bearings when equipment is operating in the following conditions:
a. With the highest load and the temperature 15 degrees Fahrenheit above the outdoor summer temperature as specified in Section 01_81_50 - Design Criteria.

C. Grease lubricated, except those specified to be factory sealed:
    1. Fit with easily accessible grease supply, flush, drain, and relief fittings.
    2. Lubrication lines and fittings:
        a. Lines: Minimum 1/4-inch diameter stainless steel tubing.
        b. Multiple fitting assemblies: Mount fittings together in easily accessible location.
        c. Use standard hydraulic-type grease supply fittings:
            1) Manufacturers: One of the following or equal:
                a) Alemite.
                b) Zerk.

D. Ratings: In accordance with ABMA 9 or ABMA 11 L10 life for bearings rating life of not less than 50,000 hours.

## 2.04 FLANGED PIPING CONNECTIONS

A. Unless specified otherwise in the Technical Sections or indicated on the Drawings, provide flat face flanges.

## 2.05 ASSEMBLY FASTENERS

A. Stainless steel, Type 316:
    1. Bolts: In accordance with ASTM A193, Grade B8M, Class 2, heavy hex.
    2. Nuts: In accordance with ASTM A194, Grade B8M, heavy hex.
    3. Washers: Alloy group matching bolts and nuts.

## 2.06 GUARDS AT MOVING COMPONENTS

A. On rotating components that are within 7.5 vertical feet of an operating floor or platform.

B. Allow visual inspection of moving parts without removal.

C. Allow access to lubrication fittings.

D. Easily removable for maintenance.

E. Materials:
    1. Sheet metal: Carbon steel, 12-gauge minimum thickness, hot-dip galvanized after fabrication.
    2. Fasteners: Type 316 stainless steel.

## 2.07 SHOP FINISHES

A. Manufacturer’s standard primer and finish coatings.
    1. Primer only if field coatings are to be applied.

## 2.08 MOUNTING AND LIFTING PROVISIONS FOR EQUIPMENT

A. Equipment bases and base plates:
   1. Provide equipment bases with machined support pads, dowels for alignment for mating of adjacent items, openings for electrical conduits, and openings to facilitate grouting.
   2. Provide jacking screws in bases and supports for equipment and for equipment weighing 500 pounds or more.
   3. Materials:
      a. Match equipment material or steel.
      b. Coating: Match equipment.

B. Steel support frames:
   1. Carbon steel:
      a. At exterior locations and at interior wet or moist locations, provide continuous welds on both sides to close seams and edges between steel members.
      b. Grind closure welds smooth.

C. Lifting lugs or eyes:
   1. Equipment units weighing 50 pounds or more:
      a. Provide with lifting lugs or eyes to allow removal with lifting device.

## 2.09 NAMEPLATES

A. Fastened to equipment at factory in an accessible and visible location.

B. Metal engraved or stamped with text, holes drilled or punched for fasteners.

C. Material: Aluminum or stainless steel.

D. Fasteners: Number 4 or larger oval head stainless steel screws or drive pins.

E. Text:
   1. Manufacturer’s name, equipment model number, equipment serial number, and identification tag number.
   2. Additional items indicated in the Technical Sections.
   3. Indicate the following additional information as applicable:
      a. Maximum and normal rotating speed.
      b. Service class in accordance with applicable standards.
   4. Include for pumps:
      a. Rated total dynamic head in feet of fluid.
      b. Rated flow in gallons per minute.
      c. Impeller, gear, screw, diaphragm, or piston size.
   5. Include for motors:
      a. Drive speed.
      b. Motor horsepower with rated capacity.
   6. Include for gear reduction units:
      a. AGMA class of service.
      b. Service factor.
      c. Input and output speeds.

## 2.10 PUMP SHAFT COUPLINGS

A. General:
   1. Type and ratings: Non-lubricated designed for not less than 50,000 hours of operating life.
   2. Sizes: Provide as recommended by manufacturer for specific application, considering horsepower, speed of rotation, balance, and type of service.
   3. Suitable for an ambient temperature range between -40 degrees to +200 degrees Fahrenheit.

B. Close-couplings for electric-motor-driven equipment:
   1. Manufacturers: One of the following or equal:
      a. Lovejoy.
      b. T.B. Woods.
   2. Provide flexible couplings designed to accommodate angular misalignment, parallel misalignment, and end float.
   3. Manufacture flexible component of coupling from synthetic rubber or urethane.
   4. Provide service factor of 2.5 for electric motor drives and 3.5 for engine drives.
   5. Do not allow metal-to-metal contact between driver and driven equipment.

C. Flexible couplings for direct connected electric-motor-driven equipment:
   1. Manufacturers: One of the following or equal:
      a. Rexnord.
      b. T.B. Woods.
   2. Provide flexible couplings designed to accommodate shock loading, vibration, and shaft misalignment or offset.
   3. Provide flexible connecting element of rubber and reinforcement fibers.
   4. Provide service factor of 2.0.
   5. Connect stub shafts through collars or round flanges, firmly keyed to their shafts with neoprene cylinders held to individual flanges by through pins.

## 2.11 PUMP SEAL CHAMBER AND SEALS

A. Seal chamber (stuffing box):
   1. Large enough to retrofit with double mechanical seal.

B. Seal types: Based on the following and as specified in the Technical Section:
   1. Type 1: Packing:
      a. Provide when specified in the Technical Section for wastewater, non-potable water, and sludge applications:
         1) Asbestos free.
         2) PTFE (Teflon™) free.
         3) Braided graphite.
         4) Manufacturers: One of the following or equal:
            a) Chesterton, 1400.
            b) John Crane.
      b. Provide when specified for drinking water service:
         1) Asbestos free.
         2) Material: Braided PTFE (Teflon™).

3) Manufacturers: One of the following or equal:
   a) Chesterton, 1725.
   b) John Crane.

c. Design:
   1) Packing gland to allow adjustment and repacking without dismantling pump, except to open up stuffing box.
   2) Seal chamber (stuffing box) large enough to retrofit with double mechanical seal.
   3) Manufacturers: One of the following or equal:
      a) Chesterton, 1725.
      b) John Crane.

## 2.12 SHIPPING

A. Prior to shipment of equipment:
   1. Bearings (and similar items):
      a. Pack separately or provide other protection during transport.
      b. Greased and lubricated.
   2. Gear boxes:
      a. Oil filled or sprayed with rust preventive protective coating.
   3. Fasteners:
      a. Inspect for proper torques and tightness.

## PART 3 EXECUTION (NOT USED)

END OF SECTION

# SECTION 46_05_94

# MECHANICAL EQUIPMENT TESTING

## PART 1 GENERAL

### 1.01 SUMMARY

A. Section includes:
   1. Testing of mechanical equipment and systems.

### 1.02 REFERENCES

A. American Gear Manufacturers Association:
   1. AGMA 6000-B96 - Specification for Measurement of Linear Vibration on Gear Units.

B. American National Standards Institute (ANSI):
   1. S1.4 - Specification for Sound Level Meters.

C. Hydraulic Institute (HI).

D. National Institute of Standards and Technology (NIST).

### 1.03 SUBMITTALS

A. Provide Source Test Plans as specified in Section 01_75_17 - Commissioning.

B. Operation and maintenance manuals:
   1. As specified in Section 01_78_24 - Operation and Maintenance Manuals.
   2. Include motor rotor bar pass frequencies for motors larger than 500 horsepower.

## PART 2 PRODUCTS (NOT USED)

## PART 3 EXECUTION

### 3.01 GENERAL

A. Commissioning of equipment as specified in:
   1. This Section.
   2. Section 01_75_17 - Commissioning.

B. Provide necessary test instrumentation that has been calibrated within 1 year from date of test to recognized test standards traceable to the NIST or approved source.
   1. Properly calibrated field instrumentation permanently installed as a part of the Work may be utilized for tests.
   2. Prior to testing, provide signed and dated certificates of calibration for test instrumentation and equipment.

C. Test measurement and result accuracy:
   1. Use test instruments with accuracies as recommended in the appropriate referenced standards. When no accuracy is recommended in the referenced standard, use 1 percent or better accuracy test instruments.
      a. Improved (lower error tolerance) accuracies specified elsewhere prevail over this general requirement.
   2. Do not adjust results of tests for instrumentation accuracy.
      a. Measured values and values directly calculated from measured values shall be the basis for comparing actual equipment performance to specified requirements.

## 3.02 VARIABLE SPEED EQUIPMENT TESTS

A. Establish performance over the entire speed range and at the average operating condition.

B. Establish performance curves for the following speeds:
   1. Speed corresponding to the rated maximum capacity.
   2. Speed corresponding to the minimum capacity.
   3. Speed corresponding to the average operating conditions.

## 3.03 PUMP TESTS - ALL LEVELS OF TESTING

A. Test in accordance with the following:
   1. Applicable HI standards.
   2. This Section.
   3. Equipment sections.

B. Test tolerances: In accordance with appropriate HI standards, except the following modified tolerances apply:
   1. From 0 to plus 5 percent of head at the rated design point flow.
   2. From 0 to plus 5 percent of flow at the rated design point head.
   3. No tolerance for head and flow when ranges are specified.
   4. No negative tolerance for the efficiency at the rated design point and other specified conditions.
   5. Use of specified test tolerances shall not result in motor overload while operating at any point on the supplied pump operating head-flow curve, including runout.
   6. No positive tolerance for vibration limits. Vibration limits and test methods in HI standards do not apply. Use limits and methods specified in this or other sections of the Specifications.

## 3.04 DRIVERS TESTS

A. Test motors as specified in Section 26_05_10 - Medium Voltage Motors.

B. Test other drivers as specified in the equipment section.

## 3.05 NOISE REQUIREMENTS AND CONTROL

A. Perform noise tests in conjunction with vibration test analysis.

B. Make measurements in relation to reference pressure of 0.0002 microbar.

C. Make measurements of emitted noise levels on sound level meter meeting or exceeding ANSI S1.4, Type II.

D. Set sound level meter to slow response.

E. Unless otherwise specified, maximum free field noise level not to exceed 85 dBA measured as sound pressure level at 3 feet from the equipment.

## 3.06 PRESSURE TESTING

A. Hydrostatically pressure test pressure containing parts at the appropriate standard or code required level above the equipment component specified design pressure or operating pressure, whichever is higher.

## 3.07 INSPECTION AND BALANCING

A. Statically and dynamically balance each of the individual rotating parts as required to achieve the required field vibration limits.

B. Statically and dynamically balance the completed equipment rotating assembly and drive shaft components.

C. Furnish copies of material and component inspection reports, including balancing reports for equipment system components and for the completed rotating assembly.

D. Critical speed of rotating equipment:
   1. Satisfy the following:
      a. The first lateral and torsional critical speed of all constant, variable, and 2-speed driven equipment that is considered rigid such as horizontal pumps, non-clog pumps, blowers, air compressors, and engines shall be at least 25 percent above the equipment's maximum operating speed.
      b. The first lateral and torsional critical speed of all constant, variable, and 2-speed driven equipment that is considered flexible or flexibly mounted such as vertical pumps (vertical in-line and vertical non-clog pumps excluded) and fans shall at least 25 percent below the equipment's lowest operating speed.
      c. The second lateral and torsional critical speed of all constant, variable, and 2-speed equipment that is considered flexible or flexibly mounted shall be at least 25 percent above the maximum operating speed.

E. Vibration tests:
   1. Definitions:
      a. Root mean square: For pumps operating at speeds greater than 600 revolutions per minute (rpm), the vibration measurement shall be measured as the overall velocity in inches per second root mean square (RMS).
      b. Peak-to-peak displacement: The root means squared average of the peak-to-peak displacement multiplied by the square root of 2.

c. Peak velocity: The root mean squared average of the peak velocity multiplied by the square root of 2.
d. Peak acceleration: The root mean squared average of the peak acceleration multiplied by the square root of 2.
e. High-frequency enveloping: A process to extract very low amplitude time domain signals associated with impact or impulse events such as bearing or gear tooth defects and display them in a frequency spectrum of acceleration versus frequency.
    1) Manufacturers: One of the following or equal:
        a) CSI, PeakVue.
        b) Rockwell Automation, Entek Group, Spike Energy analysis.
f. Rotor bar pass frequency (RBF): For detecting loose rotor bars.
g. Low speed equipment: Equipment or components of equipment rotating at less than 600 rpm.
h. High speed equipment: Equipment and equipment components operating at or above 600 rpm.
i. Preferred operating range: Manufacturer's defined preferred operating range (POR) for the equipment.
j. Allowable operating range: Manufacturer's defined allowable operating range (AOR) for the equipment.

2. Vibration instrumentation requirements:
    a. Analyzers: Use digital type analyzers or data collectors with anti-aliasing filter, 12-bit A/D converter, fast Fourier transform circuitry, phase measurement capability, time wave form data storage, high-frequency enveloping capabilities, 35 frequency ranges from 21 to 1,500,000 cycles per minute, adjustable fast Fourier transform resolution from 400 to 6,400 lines, storage for up to one hundred 3,200 line frequency spectra, data output port, circuitry for integration of acceleration data to velocity or double integration to displacement.
        1) Manufacturers: One of the following or equal:
            a) Computational Systems Inc., (CSI) Division of Emerson Process Management, Model 2120A, Data Collector/analyzer with applicable analysis software.
            b) Pruftechnik, VIBXPERT II.
    b. Analyzer settings:
        1) Units: English, inches/second, mils, and gravitational forces.
        2) Fast Fourier transform lines: 1,600 lines minimum. For motors, enough lines as required to distinguish motor current frequencies from rotational frequencies.
        3) Sample averages: 4 minimum.
        4) Maximum frequency (Fmax): 40 times rotational frequency for rolling element bearings, 10 times rotational frequency for sleeve bearings.
        5) Amplitude range: Auto select but full scale not more than twice the acceptance criteria or the highest peak, whichever is lower.
        6) Fast Fourier transform windowing: Hanning window.
        7) High pass filter: Minus 3 dB at 120 cycles per minute for high speed equipment. Minus 3 dB at 21 cycles per minute for low speed equipment.

c. Accelerometers:
1) For low speed equipment: Low frequency, shear mode accelerometer, 500 millivolts per gravitational force sensitivity, 10 gravitational force range, plus/minus 5 percent frequency response from 0.5 hertz to 850 hertz, magnetic mount.
a) Manufacturers: One of the following or equal:
(1) PCB, Model 393C.
(2) Wilcoxon Research, Model 797L.
2) For high speed equipment: General purpose accelerometer, 100 millivolts per gravitational force sensitivity, 50 gravitational force range, plus/minus 3 dB frequency response range from 2 hertz to 12,000 hertz when stud mounted, with magnetic mount holder.
a) Manufacturers: One of the following or equal:
(1) Entek-IRD, Model 943.
(2) Wilcoxon Research, Model 793.

3. Accelerometer mounting:
a. Use magnetic mounting or stud mounting.
b. Mount on bearing housing in location with best available direct path to bearing and shaft vibration.
c. Remove paint and mount transducer on flat metal surface or epoxy mount for high-frequency enveloping measurements.

4. Vibration acceptance criteria:
a. Testing of rotating mechanical equipment: Tests are to be performed by an experienced, factory trained, and independent authorized vibration analysis expert.
b. Vibration displacement limits: Unless otherwise specified, equipment operating at speeds 600 rpm or less is not to exhibit unfiltered readings in excess of the following:

| Operating Conditions and Application Data | Overall Peak-to-Peak Displacement | |
|---|---|---|
| | Field (mils) | Factory (mils) |
| Operation within the POR | 3.0 | 4.0 |
| Operation within the AOR | 4.0 | 5.0 |
| Additive value when measurement location is greater than 5 feet above foundation. | 2.0 | 2.0 |
| Additive value for slurry pumps | 2.0 | N/A |

c. Vibration velocity limits: Unless otherwise specified, is not to exceed the following peak velocity limits:

| HI Pump Type | Horsepower | Field Test | Factory Test |
|---|---|---|---|
| | | Overall RMS | Overall RMS |
| Vertical Turbine, Mixed Flow, and Propeller Pumps HI Types VS1, VS2, VS3, VS4, VS5, VS6, VS7, and VS8 | Below 268 hp | 0.13 | 0.17 |
| | 268 hp and above | 0.17 | 0.21 |
| Motors | All | See applicable motor Specification | See applicable motor Specification |

d. Equipment operation: Measurements are to be obtained with equipment installed and operating within capacity ranges specified and without duplicate equipment running.
e. Additional criteria:
    1) No narrow band spectral vibration amplitude components, whether sub-rotational, higher harmonic, or synchronous multiple of running speed, are to exceed 40 percent of synchronous vibration amplitude component without the manufacturer's detailed verification of origin and ultimate effect of such excitation.
    2) The presence of discernable vibration amplitude peaks in test Level 2 or 3 vibration spectra at bearing inner or outer race frequencies shall be cause for rejection of the equipment.
    3) For motors, the following shall be cause for rejection:
        a) Stator eccentricity evidenced by a spectral peak at 2 times electrical line frequency that is more than 40 percent of the peak at rotational frequency.
        b) Rotor eccentricity evidenced by a spectral peak at 2 times electrical line frequency with spectra side bands at the pole pass frequency around the 2 times line frequency peak.
        c) Other rotor problems evidenced by pole pass frequency side bands around operating speed harmonic peaks or 2 times line frequency side bands around rotor bar pass frequency or around 2 times the rotor bar pass frequency.
        d) Phasing problems evidenced by 1/3 line frequency side band spectral peaks around the 2 times electrical line frequency peak.
    4) The presence of peaks in a high-frequency enveloping spectra plot corresponding to bearing, gear or motor rotor bar frequencies or harmonics of these frequencies shall be cause for rejection of the equipment; since inadequate lubrication of some equipment may be a cause of these peaks, lubrication shall be checked, corrected as necessary and the high-frequency envelope analysis repeated.

5. Vibration testing results presentation:
    a. Provide equipment drawing with location and orientation of measurement points indicated.
    b. For each vibration measurement take and include appropriate data on equipment operating conditions at the time vibration data is taken; for pumps, compressors, and blowers record suction pressure, discharge pressure, and flow.
    c. When vibration spectra data required:
        1) Plot peak vibration velocity versus frequency in cycles per minute.
        2) Label plots showing actual shaft or part rotation frequency, bearing inner and outer race ball pass frequencies, gear mesh frequencies and relevant equipment excitation frequencies on the plot; label probable cause of vibration peaks whether in excess of specification limits or not.
        3) Label plots with equipment identification and operating conditions such as tag number, capacity, pressure, driver horsepower, and point of vibration measurement.
        4) Plot motor spectra on a log amplitude scale versus frequency.

d. For low speed equipment, plot peak vibration displacement versus frequency as well as velocity versus frequency.
e. Provide name of the manufacturer and model number of the vibration instrumentation used, including analyzer and accelerometer used together with mounting type.

## 3.08 TESTING LEVELS

A. Level 2 tests:
1. Level 2 Performance Test:
a. General:
1) For equipment, operate, rotate, or otherwise functionally test for at least 2 hours after components reach normal operating temperatures.
2) Operate at rated design load conditions.
3) Confirm that equipment is properly assembled.
4) Confirm the equipment moves or rotates in the proper direction.
5) Confirm shafting, drive elements, and bearings are installed and lubricated in accordance with proper tolerances.
6) Confirm that no unusual power consumption, lubrication temperatures, bearing temperatures, or other conditions are observed.
b. Pumps:
1) In accordance with general performance test requirements as specified in this Section.
2) Test 2 hours minimum for flow and head at the rated condition; for factory testing, testing may be at a reduced speeds with flow and head corresponding to the rated condition when adjusted for speed using the appropriate affinity laws.
a) Use of a test driver is permitted for factory tests when actual driver is given a separate test at its point of manufacture as specified in Section 26_05_10 - Medium Voltage Motors.
b) Use actual driver for field tests.
3) Test for flow and head at 2 additional conditions; one at 25 percent below the rated flow and one at 10 percent above the rated flow.
4) Record measured flow, suction pressure, discharge pressure, and observations on bearing temperatures and noise levels at each condition.
2. Level 2 Vibration Test:
a. Test requirement:
1) Measure filtered vibration spectra versus frequency and measure vibration phase in 3 perpendicular planes at each normally accessible bearing housing on the driven equipment, any gears and on the driver; 1 plane of measurement to be parallel to the axis of rotation of the component; measure actual rotational speeds for each vibration spectra measured using photometric or other tachometer input connected directly to the vibration data collector.
2) Vibration spectra versus frequency shall be in accordance with vibration acceptance criteria.
b. Equipment operating condition: Repeat test requirements at design specified maximum speed and at minimum speed for variable speed equipment.

c. Natural frequency test of field installed equipment:
    1) Excite the installed equipment and support system in 3 perpendicular planes, use same planes as operating vibration measurement planes, and determine the as-installed natural resonant frequency of the driven equipment, the driver, gears, and supports.
    2) Perform test at each bearing housing, at each support pedestal, and for pumps on the suction and discharge piping.
    3) Perform with equipment and attached piping full of intended service or process fluid.

3. Level 2 Noise Test:
    a. Measure filtered A-weighted overall sound pressure level in dBA for each of 8 octave band mid-points beginning at 63 hertz, measured at 3 feet horizontally from the surface of the equipment at mid-point height of the noise source.

END OF SECTION