**Wagoner County RWD #4**
**Drinking Water State Revolving Fund**
**Project # P40-1021529-01**
**Green Project Reserve Business Case**

**New High Efficiency Pump and Motor**

Summary

- Large scale District wide improvements project includes new high service pump station with three large pumps and motors.
- Estimated loan amount = $5,000,000
    - $1,400,000 new clearwell
    - $2,000,000 transmission waterline
    - $1,000,000 new storage tower
    - $100,000 existing storage tower rehabilitation
    - $500,000 new high service pump station
- Estimated energy efficiency (green) portion of loan = 10% ($500,000)
- Estimated annual energy savings up to $50,374 per year at full capacity. [1]

Background

- The District's new water treatment plant has a capacity of 8 MGD. The existing high service pump station has a capacity of 4 MGD. In order to utilize the full capacity of the water plant, the District has to construct additional pumping capacity. This project will allow the District to pump the full 8 MGD plant capacity.

Results

- The proposed new pumps (1400 GPM @ 344 TDH) will have a rated efficiency of 84.8%.[2]
- The proposed new motors (150 HP) will have a rated efficiency of 95%.[3]
- The proposed new system will be operated on variable frequency drives.

Calculated Energy Efficiency Improvements

- Standard pumps on the market have average efficiency ratings of 72.5%.
- Standard motors on the market have average efficiency ratings of 89%.[4]
- The efficiency (wire-to-water) of standard pumps and motors = 72.5% * 89% = 64.5% (pump efficiency times motor efficiency).
- The efficiency of proposed pumps and motors = 84.8% * 95% = 80.6%

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[1] Comparing the proposed high efficiency solution to the industry average, based on 2 pumps running 20 hours per day.
[2] Pump Specifications, see attached. Summer 2010.
[3] NEMA Premium Efficient Motor Specification, see attached. Summer 2010.
[4] U.S. Department of Energy, 2005. When to Purchase NEMA Premium™ Efficiency Motors. Motor Systems Tip Sheet #1. DOE/GO-102005-2019.

- To compare the efficiency of proposed pumps and motors with standard pumps and motors, divide the total efficiency of the proposed components by the efficiency of the standard components: 80.6% / 64.5% = 1.25
- Thus, the increased wire to water efficiency is 25%. This level of efficiency exceeds the 20% recommended minimum for pumps and motors.

Conclusion

- Due to using energy efficient pumps and motors, the District will have 25% energy savings equating to 251,872 kW annually for one pump operation.[5] In the future, when the full pumping capacity is necessary to meet demand, this savings will double.
- At 10 cents per kW, energy savings from high efficiency new pumps and motors will save up to $25,187 per year initially and double that in the long run.[6]


[5] Energy reductions results based on calculations using an average of 1400 GPM, 344 TDH and operation of pump for 20 hours per day.

[6] Calculations based on existing electricity bill rates.

**Appendix**

1. Calculation Spreadsheet
2. Vertical Turbine Pump Specification
3. Variable Frequency Drive (VFD) Specification

Wagoner 4 Green Case Calculations

**Summary**

| | |
|---|---|
| Estimated Loan Amount | $ 5,000,000.00 |
| 1.5 MG Clearwell | $ 1,400,000.00 |
| High Service Pump Station | $ 500,000.00 |
| 16" Transmission Line | $ 2,000,000.00 |
| 1.0 MG Storage Tank | $ 1,000,000.00 |
| Turkey Springs | $ 100,000.00 |

| | |
|---|---|
| Estimated Energy Efficiency (green) portion of loan | 10% |

**Results**

| | |
|---|---|
| The proposed new pumps will have a rated efficiency of 84.8% | 84.8% |
| The proposed new motors will have a rated efficiency of 95%. | 95% |

**Calculated Energy Efficiency Improvements**

| | |
|---|---|
| Standard pumps on the market have average efficiency ratings of | 72.5% |
| Standard motors on the market have average efficiency ratings of | 89% |
| The efficiency (wire-to-water) of standard pumps and motors = | 64.5% |
| The efficiency of proposed pumps and motors = | 80.6% |
| To compare, we divide = | 1.25 |
| Thus the increased wire-to-water efficiency = | 25% |

**Power Consumption**

Initially, one 150HP pump running 20 hours per day

| | | |
|---|---|---|
| 100% Theoretical Efficiency, 150 HP * 20 Hours per day | 2,237.00 | kw*hr/day |
| Industry Standard Efficiency Adjustment | 3,466.87 | kw*hr/day |
| Proposed High Efficiency Adjustment | 2,776.81 | kw*hr/day |
| Difference between Industry Standard & High Efficiency | 690.06 | kw*hr/day |
| Annual kw*hr savings | 251,872.37 | |

Long Term, two 150HP pumps running 20 hours per day

| | | |
|---|---|---|
| 100% Theoretical Efficiency, 150 HP * 20 Hours per day | 4,474.00 | kw*hr/day |
| Industry Standard Efficiency Adjustment | 6,933.75 | kw*hr/day |
| Proposed High Efficiency Adjustment | 5,553.63 | kw*hr/day |
| Difference between Industry Standard & High Efficiency | 1,380.12 | kw*hr/day |
| Annual kw*hr savings | 503,744.75 | |

**Cost Savings**

| | |
|---|---|
| Cost per kW*hr | $ 0.10 |
| Annual savings Initial (One 150 HP pump, 20 hours per day) | $ 25,187.24 |
| Annual savings long term (Two 150 HP pumps, 20 hours per day) | $ 50,374.47 |

# SECTION 11317

# VERTICAL TURBINE PUMPS

## PART 1 GENERAL

1.01 SCOPE OF WORK

A. This specification section covers the work necessary to furnish and install three (3) vertical turbine high service pumps.

B. Vertical turbine pump system components shall be of the same manufacturer or supplier to obtain standardization of performance, operation, spare parts, maintenance and manufacturer's services.

C. The Contractor shall furnish and install three (3) vertical turbine pumps, and all equipment required to provide a complete and operable system as described herein.

1.02 DELIVERY, STORAGE, HANDLING

A. Equipment shall be delivered to the jobsite completely factory assembled except for motor and head shaft. Individual equipment components shall be crated in structurally adequate packing containers to prevent damage during shipping, facilitate ease of handling and to provide suitable protection from weather for extended storage at the jobsite prior to installation. Packing containers shall be permanently labeled with appropriate equipment identification, shipping address and return address and packing list shall be provided with equipment at time of delivery.

B. Electrical motors and components shall be kept thoroughly dry at all times and shall be stored indoors. Equipment storage shall be protected and maintained in accordance with the manufacturer's recommendations. Equipment shall not be stored directly on the ground.

C. Contractor shall utilize equipment and tools of adequate size suitable for unloading, transporting, storing and supporting the equipment during installation. Caution shall be employed to prevent equipment damage resulting from abrupt contact with other materials or equipment.

1.03 RELATED REQUIREMENTS

SECTION 01300: Equipment Submittal Data
SECTION 09900: Painting
SECTION ?????: Electrical

1.04 QUALITY ASSURANCE

A. The vertical turbine pumps furnished under this contract shall be as manufactured by Fairbanks-Morse, Peerless Pump Company or equal to the specifications.

B. Manufacturers not name in the specifications meeting the minimum experience time requirement must submit to the engineer 15 working days prior to the bid date detailed information describing the equipment proposed to furnish. The detailed information shall be included but not limited to dimensional data, materials of construction and an installation list with address, telephone number, and an individuals name directly employed by the owner of the equipment. Plan holders will be notified of approved manufacturers by addendum 5 working days prior to bid date.

C. The pump assemblies and motors furnished under this contract shall comply with the applicable provisions of the hydraulic institute, ASTM, ANSI and NEMA mg 1.

D. The pump manufacturer shall submit to the contractor for Engineer's review, certified copies of factory hydraulic pump test results for each pump. Test results shall be submitted prior to shipment upon Engineer's request and shall show compliance with specified performance requirements.

1.05 WARRANTY

A. The manufacturer shall warrant the equipment to be of quality construction, free from defects in materials and workmanship. The warranty shall become effective upon acceptance by the owner or owner's authorized agent, or twelve (12) months after date of shipment, whichever occurs first.

B. The equipment, apparatus, and parts furnished shall be warranted from a period of one (1) year, excepting only those items that are normally consumed in service, such as oil, grease, gaskets, o-rings, etc. The manufacturer shall be solely responsible for the warranty of the equipment and all components.

C. Upon request from the Engineer and/or the owner, the manufacturer shall demonstrate proof of financial responsibility with respect to performance and delivery date. In addition, the manufacturer shall provide proof of evidence of facilities, equipment, and skills required to produce the equipment specified herein and provide technical service and replacement parts.

D. Components failing to perform as specified by the engineer, or as represented by the manufacturer, or proven defective in service during the warranty period, shall be replaced, repaired, or satisfactorily modified by the manufacturer without cost of parts or labor to the owner.

E. It is not intended the manufacturer assume liability for consequential damages or contingent liabilities arising out of failure of any product or parts thereof to operate properly, however caused by or resulting from or arising out of defects in design or manufacture, delays in delivery, replacement, or otherwise.

1.06 FACTORY TEST

A. Factory test certified by the pump manufacturer's test representative shall be performed on the pumps actually furnished, and written notice of same shall be furnished to the Engineer. Information required to be furnished at the time of test is as necessary to show conformance to specified performance. Tests shall conform to AWWA E101.

B. Motor, commercial tests shall be made, including no-load current at rated voltage, high potential, and locked rotor current.

C. Certified copies of test reports on actual pumps and motors being supplied shall be provided to Engineer for review.

1.07 DESCRIPTION

A. Quantity

| | | |
|---|---|---|
| Vertical Turbine Pump | - | Three (3) |

B. Dimensional information

1. Vertical Turbine Pump

| | | |
|---|---|---|
| Bowl nominal outside diameter | - | 12.63 inches |
| Column pipe | - | 10 inches |
| Line Shaft | - | 1.5 inches |
| Discharge head | - | 10 inch discharge by 10 inch column pipe by 16-1/2 inch motor base diameter |
| Motor | - | 150 Horse Power |
| Largest solid pump bowl pass | - | 1.00 inch diameter |

C. Design Requirements

| | | |
|---|---|---|
| Liquid Pumped | - | potable water |
| Design Flow Rate | - | 1400 GPM |
| Field head at centerline pump discharge | - | 344 feet |

(Pump manufacturer must add head losses through column assembly and discharge head to determine total required bowl head)

| | | |
|---|---|---|
| Minimum Shut-Off Head | - | 585 feet |
| Maximum NPSH Required (at Design) | - | 14.6 feet |
| Maximum Pump Speed | - | 1770 RPM |

## PART 2 PRODUCTS

### 2.01 MATERIALS

A. Vertical Turbine Pump

**Suction Manifold or Bell** - A743 grades (A15 or CA6NM Cast Iron
**Bowl** - A743 grades CA15 or CA6NM cast iron with smooth vitreous enamel coating
**Impeller** – B584 C83600 or C87500 Bronze
**Bowl Lateral Wear Ring** - Resilient, abrasion-resistant neoprene rubber reinforced with a rigid carbon steel metallic core
**Bowl Bearings** - SAE 660 Bronze and neoprene
**Bowl Sand Collar** - A743 grades CA15 or CA6NM cast iron with 303 stainless steel set screws
**Impeller Tapered Lock Bushing** - 303 stainless steel
**Bowl Flange Cap Screw or Stud and Nuts**- 303 stainless steel
**Impeller Shaft** - 416 stainless steel
**Column Pipe** - ASTM A 53, grade A, schedule 40 steel pipe
**Column Shafting** – 1045 Steel
**Column Top Flange Cap Screws** - 303 stainless steel
**Column Shaft Retainer Bearing** - Modified ASTM B-145 Bronze
**Column Shaft Bearing** - Neoprene
**Column Shaft Bearing Retainer Ring** - 303 stainless steel
**Discharge Head** - Class 30 Cast Iron
**Packing Container** - Class 30 Cast Iron
**Packing Washer** - Brass
**Packing** - Graphited Rope
**Packing Gland** - Cadmium plated Class 30 cast iron
**Packing Gland T-Bolt** - 316 Stainless Steel
**Packing Gland Clamp** - 302 Stainless Steel
**Packing Gland Nut** - 316 Stainless Steel

**Packing Gland Gasket** - Vellumoid
**Packing Gland Cap Screw** - Steel
**Top Shaft** - 416 Stainless Steel
**Top Shaft Seal Ring** - Neoprene
**Top Shaft Coupling** - 410 Stainless Steel
**Strainer -** Galvanized Steel

2.02 VERTICAL TURBINE PUMP

A. Pump suction case shall be fitted with an extra long bearing to insure additional strength and rigid support of the lower end of the pump shaft. The bearing shall be permanently packed with water resistant lithium - based grease. The ratio of length to diameter of the bearing shall be 5 to 1 or greater. A plug shall be placed at the bottom of the suction case to prevent water from flowing through the tail bearing. The bearing shall be protected from abrasive wear by a sand collar locked to the impeller shaft.

B. Pump bowls shall be free from blow holes, sand holes, and any other faults and accurately machined and fitted to close dimensions. Integrally cast vanes designed to match impellers utilized and guide water to the next stage with minimum losses and maximum efficiency shall be provided. Sand lugs shall be built into the bowl to eliminate rotation and vortexing of water borne abrasives along the bowl surfaces. Each bowl shall be fitted with an impeller seal lateral bowl wear ring to provide an additional sealing surface in the horizontal plane. Dual bowl bearings shall be furnished for each bowl utilizing fluted rubber and bronze. The top bowl shall be furnished with two (2) extra long bronze bearings, one (1) rubber bearing and a sand collar secured to the impeller shaft.

C. Impeller shall be of the enclosed radial or semi-open flow type, accurately machined, finished and mechanically balanced. Impellers shall be securely fastened to the impeller shaft with a tapered bushing. Impeller vanes and guide passages shall be hand finished. Impeller skirts will be extra long to insure long life primary sealing and extra thick for secondary sealing and machinable for wear rings.

D. Pump column pipe shall be threaded and coupled in interchangeable sections not over five (5) feet in length. The total length of the column pipe shall be as shown on the plans. The top of the column pipe shall be flanged to connect to the bottom of the discharge head. The column pipe assembly shall be furnished with accurately machined retainer bearing for concentricity at each coupling located between the butted ends of the column pipe. Bearing retainers shall contain a fluted, cutless rubber bearing designed for water lubrication. Shall be flush, butted and securely retained with dog bone bearings not acceptable.

E. Column shafting shall be of the open type and furnished in interchangeable sections not over five (5) feet in length. Shafting shall be turned, ground, polished and of ample size to operate the pump without distortion or vibrations. Shafting shall be connected with couplings machined from solid bar stock material. A relief hole shall be provided in the center of the coupling to allow escape of air and excess thread compound when the shaft ends are butted together. The top shaft shall be furnished in a two-piece configuration to allow removal of the motor without lifting over the shafting.

F. The discharge head shall be the above ground discharge type with machined mounting surface designed for standard NEMA 1 flange motor, the discharge flange shall be furnished with 125-pound ANSI drilling the discharge head shall be fitted with a packing container designed for lubrication with the pumped liquid. A threaded connection shall be provided to allow the lubrication liquid collected in the interior ring of the discharge head to be piped to a local drain. A seal ring shall provided to prevent the lubrication liquid from leakage up onto the motor bearings. Hand hole openings large enough to provide easy access to all adjustable components shall be furnished. Lifting lugs adequately designed to support the entire weight of the pump assembly shall be integrally cast into the discharge head.

G. Drive Motors

1. The motors shall be premium efficient, high-thrust rated of the squirrel-cage induction alternating current type. The motor nameplate horsepower rating shall not be exceeded at any head capacity point on the pump curve. The motor shall conform to the following:

| | |
|---|---|
| Synchronous Speed | 1,800 RPM |
| Slip | 3 percent maximum at full load |
| Voltage, phase, & Frequency | 460 volts, 3 phase, 60 Hz |
| Mounting | Vertical, hollow shaft |
| Enclosure | Weather protected, Type I |
| Service Factor | 1.15 |
| Duty Cycle | Continuous |
| Ambient Temperature Rating | 40 degrees C |
| Starting Method | Variable Frequency Drive |
| Bearing Lubrication | Manufacturer's standard |
| Bearing Bio Life | Bio Life-Average 25 Years, minimum 5 years. |
| Efficiency Rating | Premium Efficient |

2.03 SPARE PARTS

A. Spare parts for each pump shall be furnished as follows:

1. Complete set of packing
2. Complete set of gaskets
3. Complete set of "O"-Rings
4. Packing Gland
5. Packing Gland "T" Bolts

## PART 3 EXECUTION

3.01 INSTALLATION

A. The general contractor shall assume full responsibility for coordination of the entire project, including verification that all structures, piping, coating systems and equipment components be compatible. The general contractor shall initially operate each equipment system, and shall make all necessary adjustments so that each system is placed in proper operation condition.

B. Equipment and materials utilized for this project must be approved by the Engineer prior to installation. Approval for installation or incorporation in this project will be made only after submittal of manufacturer's shop and installation drawings, test results or other data as required and as specified herein.

C. Installation of equipment shall be in full conformance with the manufacturer shop drawings and requirements as approved by the Engineer. Wherever a conflict arises between manufacturer's instructions and the contract documents, the contractor shall follow the Engineer's decision at no additional cost to the owner.

3.02 WORKMANSHIP

A. Handle carefully and protect the pump and appurtenances to avoid damage. If the pump and column are laid down, support them with blocks to prevent damage.

B. Mount pump and driver on concrete base as shown on the Drawings. The size of the concrete bases shall be in accordance with the details shown.

C. Install pump with the shaft pump. Level sole plate by means of steel

wedges (steel plates and steel shims). Wedge taper shall not be greater than 1/4-inch per foot. Use double wedges to provide a level bearing surface for the pump and/or driver base. Secure each pair of wedges in their final positions with one tack weld on each side after leveling is complete. Accomplish wedging so that there is no charge of level or springing of the baseplate when the anchor bolts are tightened. Install the pump so that connections may be made to the discharge header without any springing or otherwise forcing either the pump or the header. Anchor bolt size shall be as required by the pump manufacturer. Coat bolt thread projections with lubricant to facilitate future nut removal. Provide double nuts to prevent accidental loosening.

D. Adjust pump assembly such that the driving unit is properly aligned, plumb, and level with the driven unit and the interconnecting shaft and coupling. Flexible coupling shall not be considered to compensate for misalignment.

E. After the pump and driver have been set in position, aligned and shimmed to the proper elevation, grout the space between the bottom of the sole plate and the concrete foundation with a dry, tamped-in, non-shrinking grout, prepared and installed in accordance with Section CONCRETE. The arrangement of the column shall be straight and vertical when the installation is complete.

F. Any evidence of pump or driver misalignment, noisy operation, or other signs of improper setting shall be corrected by the Contractor. Care during storage, installation and lubrication shall be in strict accordance with the manufacturer's recommendations.

3.03 ANCHORAGE

A. Anchor bolts shall be furnished for each item of equipment. Anchor bolts, together with templates or setting drawings, shall be delivered sufficiently early to permit setting the anchor bolts when the structural concrete is placed. Two nuts shall be furnished for each bolt.

B. Unless otherwise shown on the manufacturers or Engineer’s drawings or specified, anchor bolts for items of equipment mounted on base plates shall be long enough to permit 2 inches of grout beneath the baseplate, and to provide adequate anchorage into structural concrete.

C. Types of anchorage:

1. All cast-in-place anchorage, not submerged, shall be hot dipped galvanized.

2. Anchorage utilized in submerged or humid location shall be constructed from type 304 stainless steel.

3. Drill-in anchorage shall be epoxy adhesive type.

3.04 LUBRICATION

A. Equipment shall be adequately lubricated by a system which does not require more than once-a-week operator attention, does not require attention during start-up or shutdown and does not waste lubricants.

B. The contractor shall provide lubricants of the type recommended by the equipment manufacturer in sufficient quantity to fill all lubricant reservoirs and to replace all consumption during equipment initial operation, performance testing and operation prior to acceptance of equipment by the owner.

3.05 FIELD PAINTING

A. All ferrous materials which are not non-corrosive shall be painted with epoxy paint systems. Paint systems in contact with water to be used for potable public water supply systems shall be approved by the FDA for this application.

3.06 MANUFACTURER'S SERVICES

A. The Contractor shall require the manufacturer to furnish the services of a qualified field engineer to perform the following functions in the designed periods of time. These services are to be performed at the jobsite.

1. Check-out of installation, start-up of equipment and initial operator instruction. This service shall take place after all mechanical equipment associated with the control system is installed and mechanically operable.

2. After equipment is fully operational, and before Owner will assume responsibility for the operation of the equipment, the equipment manufacturer's operation specialists shall instruct the Owner's operating personnel in the care, maintenance and proper operation of the equipment.

B. Field Test

1. Prior to plant startup, all equipment described herein shall be inspected for proper alignment, quiet operation, proper connections, and satisfactory performance by means of a functional test.

2. The pumps, motors, and controls shall be given an operational test in accordance with the standards of the Hydraulic Institute. Recordings of the test shall substantiate the correct performance of the equipment at the design head, capacity, suction lift, speed and horsepower as herein specified.

C. Instructions for installation of the pump and related appurtenances shall be written and furnished by the manufacturer.

D. Operation and maintenance materials

1. The pump manufacturer shall be responsible for supplying written instruction, which shall be sufficiently comprehensive to enable the operator to operate and maintain the pump and all equipment supplied by the manufacturer. Instructions shall assume that the operator is familiar with pumps, motors, piping, valves, and controls, but that he has not previously operated and/or maintained the exact equipment supplied.

2. The instruction shall be prepared as a system manual applicable solely to the pump and equipment supplied by the manufacturer to these specifications, and shall include those devices and equipment supplied by him.

3. Operation and maintenance instruction shall be specific to the equipment supplied in accordance with these specifications. Instruction manuals applicable to many different configurations and pump stations, and which require the operator to selectively read portions of the instructions shall not be acceptable.

E. Manufacturer's Costs: All costs for the above manufacturer functions including travel, lodging, meals, and incidental shall be considered to have been included in the Contractor's lump sum bid price.

**END OF SECTION**

# SECTION 16920

# ADJUSTABLE FREQUENCY DRIVES

## PART 1 GENERAL

### 1.01 SCOPE OF WORK

A. Contractor shall provide a complete adjustable frequency AC drive controller system for the three (3) new high service pumps. The system shall be a complete, fully integrated control system provided by a single Coordinating Supplier who shall furnish all labor, equipment, materials, and incidentals required and shall supervise the installation, start-up, and testing using qualified technicians and other specialists. The supplier shall coordinate the equipment requirements with the mechanical and electrical requirements of the Contract Documents, shall integrate the equipment furnished with the requirements shown on the electrical drawings, and provide complete installation and interconnection drawings and diagrams required for installation, start-up, testing and adjustment.

B. The adjustable frequency AC drive controller system shall consist of the three (3) adjustable frequency AC drives as outlined in these specification and as shown on the Contract plans.

### 1.02 DELIVERY, STORAGE, HANDLING

A. Individual equipment components shall be crated in structurally adequate packing containers to prevent damage during shipping, facilitate ease of handling and to provide suitable protection from weather for extended storage at the jobsite prior to installation. Packing containers shall be permanently labeled with appropriate equipment identification, shipping address and return address. Packing list shall be provided with equipment at time of delivery.

B. Electrical equipment shall be kept thoroughly dry at all times and shall be stored indoors. Equipment storage shall be protected and maintained in accordance with the manufacturer's recommendations. Equipment shall not be stored directly on the ground.

C. Contractor shall utilize equipment and tools of adequate size suitable for unloading, transporting, storing and supporting the equipment during installation. Caution shall be employed to prevent equipment damage

resulting from abrupt contact with other materials or equipment.

## 1.03 QUALITY ASSURANCE

A. The Contractor's attention is directed to the fact that the adjustable frequency AC drive controller system is an integrated system which shall be furnished, factory assembled and integrated by one manufacturer or supplier.

B. The materials or equipment so specified have been selected as being suitable for the service anticipated and will be regarded as standard. The Contractor should prepare his bid on the basis of the particular equipment and materials specified. The awarding of the contract will constitute a contractual obligation on the part of the Contractor to furnish the specified equipment and materials.

C. Should the bidder desire to submit for consideration an unspecified product or products as equal to those specified, the Bidder shall furnish with his proposal, a listing of any product or products he proposes to incorporate in the work other than those specified herein by manufacturer's name along with any deduction the Contractor wishes to offer for consideration in lieu of the alternate product or products. This listing shall be accomplished by descriptive information for each unspecified product or products, including, as applicable, detailed drawings and specifications, certified operation data, and experience records. The Owner reserves the right to reject any unspecified product or products submitted which require changes in design construction or other changes which may increase the contract price for the performance of any of the separate contracts of the project. The alternate product or products submitted by the Bidder shall meet the requirements of the equipment specified by name herein and shall be approved by the Engineer.

D. To ensure quality and minimize infantile failures at the jobsite, the complete VFD shall be tested by the manufacturer. The VFD shall operate a dynamometer at full load and the load and speed shall be cycled during the test.

E. All optional features shall be functionally tested at the factory for proper operation.

F. Factory test documentation shall be available upon request.

## 1.04 SUBMITTALS

A. Submit manufacturer=s performance data including dimensional drawings, power circuit diagrams, installation and maintenance manuals, warranty description, VFD’s FLA rating, certification agency file numbers and catalog information and cut-sheets for all major components.

B. The specification lists the minimum VFD performance requirements for this project. Each supplier shall list any exceptions to the specification. If no departures from the specification are identified, the supplier shall be bound by the specification.

C. The entire System shall be designed, coordinated and supplied by a company regularly engaged in the business of designing and fabricating adjustable frequency AC drive controller systems for a minimum of fifteen (15) years. Acceptable drive manufacturers are Danfoss, or approved equal.

## 1.05 WARRANTY

A. The manufacturer shall warrant the equipment to be of quality construction, free from defects in materials and workmanship. The warranty shall become effective upon acceptance by the Owner or Owner's authorized agent, or six (6) months after date of shipment, whichever occurs first.

B. The equipment, apparatus, and parts furnished shall be warranted for a period of 18 months from the date of shipment, or 12 months from the date of installation, whichever is shortest. The manufacturer shall be solely responsible for the warranty of the equipment and all components.

C. Upon request from the Engineer and/or the Owner, the manufacturer shall demonstrate proof of financial responsibility with respect to performance and delivery date. In addition, the manufacturer shall provide proof of evidence of facilities, equipment, and skills required to produce the equipment specified herein and provide technical service and replacement parts.

D. Components failing to perform as specified by the Engineer, or as represented by the manufacturer, or proven defective in service during the warranty period, shall be replaced, repaired, or satisfactorily modified by the manufacturer without cost of parts or labor to the Owner.

## 1.06 REFERENCES

A. UL 508C
B. CE
C. NEC
D. Canadian Underwriters Laboratory (CUL)
E. ISO 9001
F. ISO 14001

# PART 2 PRODUCTS

## 2.01 MANUFACTURERS

A. The variable frequency drives shall be Danfoss FC202 Aqua Series or

approved equal.

## 2.02 GENERAL

A. Furnish complete VFD as specified herein or in the equipment schedule for loads designated to be variable speed. VFD's shall be both constant and variable torque rated.

B. The VFD shall convert incoming fixed frequency three-phase AC power into a variable frequency and voltage for controlling the speed of three-phase AC induction motors. The VFD shall be a six-pulse input design, and the input voltage rectifier shall employ a full wave diode bridge; VFD's utilizing controlled SCR rectifiers shall not be acceptable. The output waveform shall closely approximate a sine wave. The VFD shall be of a PWM output design utilizing current IGBT inverter technology and voltage vector control of the output PWM waveform.

C. The VFD shall include a full-wave diode bridge rectifier and maintain a displacement power factor of near unity regardless of speed and load.

D. The manufacturer of the VFD shall demonstrate a continuous period of manufacturing and development of VFD's for the first 25+ years. VFD's that are brand-labeled are not acceptable.

E. The VFD shall produce an output waveform capable of handling maximum motor cable distances of up to 1,000 ft. (unshielded) without tripping.

F. The VFD shall utilize VVCPlus, an output voltage-vector switching algorithm, or equivalent, in both variable and constant torque modes. VVCPlus provides rated RMS fundamental voltage from the VFD. This allows the motor to operate at a lower temperature rise, extending its thermal life. VFD's that cannot produce rated RMS fundamental output voltage or require the input voltage to be increased above motor nameplate value to achieve rated RMS fundamental output voltage are not acceptable.

G. The VFD selected must be able to source the motor's full load nameplate amperage (fundamental RMS) on a continuous basis, and be capable of running the motor at its nameplate RPM, voltage, current, and slip without having to utilize the service factor of the motor.

H. The VFD will be capable of running either variable or constant torque loads. In variable torque applications, the VFD shall provide a CT-start feature and be able to provide full torque at any speed up to the base speed of the motor. In either CT or VT mode, the VFD shall be able to provide it=s full rated output current continuously and 110% of rated current for 60 seconds.

I. An Automatic Energy Optimization (AEO) selection feature shall be provided in the VFD to minimize energy consumption in variable torque applications.

This feature shall dynamically adjust output voltage in response to load, independent of speed. This feature shall incorporate power factor compensation. Output voltage adjustment based upon frequency alone is not acceptable for single motor VT configurations.

J. For multi-motor variable torque configurations, user-selectable load profile curves including VT-High, VT-Medium, and VT-Low shall be provided to ensure easy commissioning and improved energy efficiency. VFD's requiring the operator to assign load torque data-points to create a V/Hz profile are not acceptable.

K. Switching of the input power to the VFD shall be possible without interlocks of damage to the VFD at a minimum interval of 2 minutes.

L. Switching of power on the output side between the VFD and the motor shall be possible with no limitation or damage to the VFD and shall require no additional interlocks.

M. An Automatic Motor Adaptation function shall measure motor stator resistance and reactance to optimize performance and efficiency. It shall not be necessary to spin the motor shaft or decouple the motor from the load to accomplish this optimization. Additionally, the parameters for motor resistance and motor reactance shall be user-programmable.

N. The VFD shall have temperature controlled cooling fans for quiet operation, minimized internal losses, and greatly increased fan life.

O. VFD shall provide full torque to the motor given input voltage fluctuations of up to □10% of the rated input voltage. Additionally, sustained line voltage reductions up to 15% shall not cause the VFD to trip.

P. The VFD shall provide dual built-in DC link reactors to minimize power line harmonics and to provide near unity power factor. VFD's without a DC link reactor shall provide a 5% impedance line side reactor, at a minimum.

Q. The VFD shall be manufactured in a facility certified to comply with the requirements of ISO 14001.

## 2.03 PROTECTIVE FEATURES

A. VFD shall have input surge protection utilizing MOV's, spark gaps, and zener diodes to withstand surges of 2.3 times line voltage for 1.3msec.

B. VFD shall include circuitry to detect phase imbalance and phase loss on the input side of the VFD.

C. VFD shall auto-derate the output voltage and frequency to the motor if an input phase is lost if it is desirable to maintain operation without decreasing

the life expectancy of the VFD. The use of this feature shall be user selectable and export a warning during the event.

D. VFD shall include current sensors on all three output phases to detect and report phase loss to the motor. The VFD will identify which of the output phases is low or lost.

E. VFD shall auto-derate the output voltage and frequency to the motor in the presence of sustained ambient temperatures higher than the normal operating range, so as not to trip on an inverter temperature fault. The use of this feature shall be user-selectable and a warning will be exported during the event.

## 2.04 INTERFACE FEATURES

A. VFD shall provide an alphanumeric backlit display keypad which may be remotely mounted using standard 9-pin cable. VFD may be operated with keypad disconnected or removed entirely. Keypad may be disconnected during normal operation without the need to stop the motor or disconnect power to the VFD.

B. VFD shall display all faults in plain text; VFD's which can display only fault codes are not acceptable.

C. The keypad shall feature a 4-line display, and be capable of digitally displaying up to four separate operational parameters or status values simultaneously (including process values with the appropriate engineering unit) in addition to Hand/Off/Auto, Local/Remote, and operating status.

D. Two lines of the display shall allow A free text programming so that a description, or the actual name, of the equipment being controlled by the VFD can be entered into the display.

E. Keypad shall provide an integral H-O-A (Hand-Off-Auto) and Local-Remote selection capability, and manual control of speed locally without the need for adding selector switches, potentiometers, or other devices.

F. All VFD's shall be of the same series, and shall utilize a common control card and LCP (keypad/display unit) throughout the rating range. The control cards and keypads shall be interchangeable.

G. VFD keypad shall be capable of storing drive parameter values in non-volatile RAM uploaded to it from the VFD, and shall be capable of downloading stored values to the VFD to facilitate programming of multiple drives in similar applications, or as a means of backing up the programmed parameters.

H. VFD display shall indicate which digital inputs are active, and the status of

each relay.

I. VFD display shall indicate the value of any voltage or current signal connected to the analog input terminals.

J. VFD display shall indicate the value of the current on the analog output terminals.

K. A red FAULT light, a yellow WARNING light and a green POWER-ON light shall be provided. These indications shall be visible both on the keypad and on the VFD when the keypad is removed.

L. Dual protection shall be provided to prevent unauthorized changes to the programming of the VFD. The parameters can be locked via a digital input and/or the unit can be programmed not to allow an unauthorized user to change the parameter settings.

M. A quick setup menu with factory preset typical parameters shall be provided on the VFD to facilitate commissioning. Use of macros shall not be required.

N. A digital elapsed time meter and kilowatt hour meter shall be provided in the display.

O. VFD shall provide full galvanic isolation with suitable potential separation from the power sources (control, signal, and power circuitry within the drive) to ensure compliance with PELV requirements and to protect PLC's and other connected equipment from power surges and spikes.

P. All inputs and outputs shall be optically isolated. Isolation boards between the VFD and external control devices shall not be required.

Q. There shall be eight fully programmable digital inputs for interfacing with the systems external control and safety interlock circuitry.

R. The VFD shall have two voltage analog signal inputs and one current signal input, and shall accept a direct-or-reverse acting signal. Analog reference inputs accepted shall include 0-10 V dc, 0-20 mA and 4-20 mA.

S. Two programmable analog outputs shall be provided for indication of drive status. These outputs shall be programmable for output speed, voltage, frequency, motor current and output power.

T. The VFD shall provide two user programmable relays with 31 selectable functions. One form >A= 50VAC and one form >C= 230VAC/2A rated dry contact relay outputs shall be provided.

U. Floating point control interface shall be provided to increase/decrease frequency in response to external switch closures.

V. The VFD shall accept a NC motor temperature overtemperature switch input, as well as possess the capability to accept a motor thermistor input.

W. The VFD shall store in memory the last 20 faults and record all operational data.

X. Run permissive circuit shall be provided to accept a system ready signal to ensure that the VFD does not start until isolation valves or other types of auxiliary equipment are in the proper state for VFD operation. The run permissive circuit shall also be capable of sending an output signal as a start command to actuate external equipment before allowing the VFD to start.

Y. The VFD shall be equipped with a standard RS-485 serial communications port utilizing either the Danfoss FC or Profibus DPV1 protocol, and also be capable of supporting the following communications protocols by the use of an integrally mounted, field-installable option board: Profibus PA, DeviceNet, or Modbus RTU.

Z. The VFD shall be supplied with a standard RS-485 serial communications data port. A Windows7 compatible software to display all monitoring, fault, alarm, and status signals shall be available. This software shall allow parameter changes, storage of all VFD operating and setup parameters, and remote operation of the VFD.

## 2.05 ADJUSTMENTS

A. The VFD shall have an adjustable output switching frequency.

B. Four complete programming parameter setups shall be provided, which can be locally selected through the keypad or remotely selected via digital input(s), allowing the VFD to be programmed for up to four alternate control scenarios without requiring parameter changes.

C. In each programming set up, independent acceleration and deceleration ramps shall be provided. Acceleration and deceleration time shall be adjustable over the range from 0 to 3,600 seconds to base speed.

D. The VFD shall have four programmable skip frequencies with adjustable bandwidths to prevent the driven equipment from running at a mechanically resonant frequency.

E. VFD shall include an automatic accel/decel ramp-time function to prevent nuisance tripping and simplify start-up.

F. In each programming setup, independent current limit settings, programmable between 50% and 110% of the drives output current rating, shall be provided.

G. A built-in PID controller shall be able to accept two feedback signals and two set-points. Response to the set-point/feedback differences must be programmable to allow choices between different calculation methods for the feedback signals.

H. PID parameter settings shall be adjustable while the VFD is operating, to aid in tuning the loop at start up. The VFD will also be capable of simultaneously displaying setpoint reference and feedback values with appropriate engineering units, as well as output frequency, output current, and run status while programming the PID function.

I. The VFD will include a loss of follower function to detect the loss of process feedback or reference signals with a live-zero value, with a user-selectable choice of responses (go to set speed, min speed, max speed, stop, stop and trip).

J. A Sleep Mode function shall be provided to reduce wear and heating of the blower and other equipment in periods where system demands are minimal. This function will operate in both open and closed loop modes:

1. In closed loop process control, when the output speed drops to a user-programmed minimum value (sleep frequency) for a specified time (sleep mode timer), the drive will enter sleep mode and either go into standby or boost mode before entering standby. The drive shall automatically restart the motor once the output of the PID processor exceeds a programmable value wake up frequency. Boost mode shall prevent short-cycling of the motor by temporarily adjusting the setpoint by a user programmable percentage. Upon reaching this valve, the unit will go into standby.

2. In open loop, the drive shall be capable of entering sleep mode if the input reference drops below a user programmable value. When the input reference increases above a programmable reference, the drive will automatically start.

K. An integral motor alternation function shall be provided to enable the drives output to alternate between two motors. The alternation interval shall be programmable in hours. The function shall operate relays as required to control the motor alternation sequence. A dwell time shall be integral to the function to prevent damage to the motor contactors.

L. The VFD will include a user selectable Reset function, which enables the selection of between zero and twenty restart attempts after any self-clearing fault condition (under-voltage, over-voltage, current limit, inverter overload and motor overload), or the selection of an infinite number of attempts. The time between attempts shall be adjustable from 0 through 600 seconds.

M. An automatic on delay function may be selected from 0 to 120 seconds.

N. The VFD will include a user-selectable Auto-Restart function which enables the VFD to power up in a running condition after a power loss, to prevent the need to manually reset and restart the VFD. VFD shall catch a rotating motor operating either in forward or reverse at up to full speed.

## 2.06 SERVICE CONDITIONS

A. The enclosure shall be sized to allow the drive to operate at full rated current continuously with no additional cooling in ambient temperatures from 14F to 104F (-10 to 40C), at altitudes up to 3,300 ft. without derating.

B. The VFD shall withstand storage temperatures from -40F to 158F (-40 to 70C).

C. 0 to 95% relative humidity, non-condensing.

D. VFD's rated nominal 460 Vac shall meet all specifications when operating from 440 to 500 Volts □10%, three phase, 45 to 66 Hz.

E. No side clearance shall be required for cooling of wall mount units and all power and control wiring shall be done from the bottom.

## 2.07 DRIVE RATINGS

A. Input Voltage - 460 VAC

B. Motor Output - 150 H.P.

C. Maximum Continuous Drive Output Current - 240.0 AMPS

D. Maximum Intermittent Drive Output Current - 264.0 AMPS

E. Enclosure - NEMA 1

# PART 3 EXECUTION

## 3.01 GENERAL

A. The general contractor shall assume full responsibility for coordination of the entire project, including verification that all equipment components are compatible. Contractor to verify that jobsite conditions for installation meet factory recommended and code required conditions for VFD installation prior to start-up, including clearance spacing, temperature, contamination, dust, and moisture of the environment. Separate conduit installation of the motor wiring, power wiring, and control wiring, and installation per the

manufacturer’s recommendations shall be verified.

B. The VFD is to be covered and protected from installation dust and contamination until the environment is cleaned and ready for operation. The VFD shall not be operated while the unit is covered.

C. Equipment and materials utilized for this project must be approved by the Engineer prior to installation. Approval for installation or incorporation in this project will be made only after submittal or manufacturer's shop and installation drawings, test results or other data as specified herein.

D. Installation of equipment shall be in full conformance with the manufacturer's shop drawings and requirements as approved by the Engineer. Wherever a conflict arises between manufacturer's instructions and the contract documents, the contractor shall follow the Engineer's decision at no additional cost to the Owner.

## 3.02 WORKMANSHIP

A. Handle carefully and protect the equipment and appurtenances to avoid damage.

B. The equipment shall be safely secured to the wall and floor in accordance with the Engineer's design drawings. All plumbing and electrical shall be in accordance with state and federal codes to ensure proper operation of the adjustable frequency AC drive controller system, as-well-as the safety of plant personnel.

C. Any evidence of improper installation shall be corrected by the Contractor. Care during storage, installation and startup shall be in strict accordance with manufacturer's recommendations.

## 3.03 MANUFACTURER'S SERVICES

A. The Contractor shall require the manufacturer to furnish the services of a qualified field engineer to perform the following functions in the designated period of time. These services are to be performed at the jobsite. A minimum of one (1) visit to the job site shall be required.

1. Check-out of installation, start-up of equipment and initial operator instruction. This service shall take place after all mechanical equipment associated with the blower system is installed and mechanically operable.

2. After equipment is fully operational, and before Owner will assume responsibility for the operation of the equipment, the equipment manufacturer's operation specialists shall instruct the Owner's operating personnel in the care, maintenance and proper operation of

the equipment.

B. Field Test

1. During plant start-up all equipment described herein shall be inspected for proper connections and satisfactory performance by means of a function test.

2. The equipment system and associated accessories shall be field tested to verify adequate performance. The units shall be set at the Engineer's desired feed rate in preparation of plant operation.

3. Units apparently failing to meet the Specifications must be corrected to provide proper service. Should the problem persist due to a flaw in material and/or in the design of the equipment, new equipment must be provided by the Contractor to meet the specifications.

C. Instructions for installation of the equipment system and related appurtenances shall be written and furnished by the manufacturer.

D. Operation and Maintenance

1. The equipment system manufacturer shall be responsible for supplying written instruction, which shall be sufficiently comprehensive to enable the operator to operate and maintain all equipment supplied by the manufacturer. Instructions shall assume the operator is familiar with adjustable frequency AC drive controller systems, but he/she has not previously operated and/or maintained the exact equipment supplied.

2. The instruction shall be prepared as a system manual applicable solely to the equipment supplied by the manufacturer, and shall include those devices and equipment supplied by him.

3. Operation and maintenance instruction shall be specific to the equipment supplied in accordance with these specifications.

E. Manufacturer's Cost

1. All costs for the above manufacturer's functions including travel, lodging, meals and incidentals shall be considered to have been included in the contract bid price.

**END OF SECTION**