

SECTION 43 32 56
MEMBRANE EQUIPMENT SYSTEM
(MEMBRANE BIOREACTOR)

PART 1 GENERAL

1.01 REFERENCES

- A. Refer to Section 01 33 23, Submittal Procedures, for submittal requirements and procedures to be provided under this Contract by the Membrane Equipment System (MES) supplier.
- B. Refer to Section 01 88 15, Anchorage and Bracing, for anchorage and bracing requirements.
- C. Refer to the following sections for electrical requirements:
 - 1. Section 26 05 02, Basic Electrical Requirements.
 - 2. Section 26 05 04, Basic Electrical Materials and Methods.
 - 3. Section 26 05 10, Network Communication Systems.
 - 4. Section 26 05 26, Grounding and Bonding for Electrical Systems.
 - 5. Section 26 20 00, Low-Voltage AC Induction Motors.
 - 6. Section 26 24 19, Low-Voltage Motor Control.
 - 7. Section 26 29 23, Low-Voltage Adjustable Frequency Drive System.
 - 8. Section 26 43 00, Surge Protective Devices.
- D. Refer to Section 40 90 00, Instrumentation and Control for Process Systems.
- E. Refer to Section 40 99 90, Package Control Systems, and control panel requirements.

1.02 DEFINITIONS

- A. Backwash or Backpulse: Any instance a membrane train is taken offline and water, and/or chemical solution is pumped through the membranes in the reverse direction of the permeate flow.
- B. Days: Defined as calendar days.
- C. Design Flow: Equivalent to "Net Flow."
- D. Instantaneous Flux: Equals the permeate flow rate, in gallons per day, produced during the service cycle divided by the total membrane outside surface area in square feet. Service cycle is defined as the period of continuous permeation between the membrane relaxation, backwash, or backpulse, where the MES uses relaxation or backwash/backpulse as a

permeability maintenance method. Units of “Instantaneous Flux” are gallons per square foot per day (gfd).

- E. Large Membrane Subunit: A group of small membrane subunits sharing a common air and permeate connection. Depending on the membrane system supplier, this may be referred to as a “cassette,” “rack,” “unit,” or by other terms.
- F. Maintenance Clean: Any instance a membrane train is taken offline for application of a chemical solution without draining the membrane tank or taking the membranes out of the tank, that is not considered part of the normal backwash cycle or recovery clean. During a maintenance clean, membranes are immersed in mixed liquor.
- G. Membrane Effluent (MEF): Filtrate/Permeate extracted from mixed liquor through membranes.
- H. Membrane Equipment System (MES): A complete set of membranes assembled into Small Membrane Subunits, and mounted in Large Membrane Subunits, and all equipment, appurtenances, and control to enable operation of the system to separate treated water from mixed liquor.
- I. Membrane Tank: One isolatable unit of the overall membrane facility that may contain one or more parallel rows of large membrane subunits. The liquid contents in the Membrane Tank shall be hydraulically connected to the bioreactors upstream. The Membrane Tank shall be capable of draining and filling as a single entity.
- J. Membrane Train:
 - 1. One of multiple functional units of the MES that operates in parallel, and distinctly, from other trains, and that includes: A grouping of large membrane subunits located within a single tank, one or more common membrane permeate headers and pumps with one or more membrane permeate pumps per membrane train, one programmable logic controller (PLC), one operator interface unit (OIU), and a common air supply header. A train operates as a single entity for operation, backwash/backpulsing, relaxing, maintenance, cleaning, or recovery cleaning.
- K. Net Flow: Equals the net flow rate of treated effluent (permeate), in million gallons per day (mgd), over a 24-hour period of continuous operation, calculated as flow produced minus backwash and cleaning water, and accounting for periods of relaxation, backwashing, and cleaning.
- L. Net Flux: Equals the total amount of permeate produced by the membrane system over a representative period that is available for downstream discharge (after deduction of backwash and cleaning water) divided by the total

membrane outside surface area in square feet. Units of “Net Flux” are gfd. Representative period includes production, relaxation, backpulsing, chemical cleaning, etc., as appropriate for flow duration being considered.

- M. NSF: National Sanitation Foundation.
- N. Permeability: Equals the instantaneous flux divided by the TMP. The units of permeability are gfd/pounds per square inch (psi).
- O. Production Capacity: Equivalent to “Net Flow.”
- P. Recovery Clean: Any manual, automated or semi-automated procedure occurring less than once per month that uses one or more cleaning chemicals to reverse the effects of membrane fouling. This involves isolating a membrane train and filling membrane tank or permeate side of membrane unit fully or partially with cleaning chemicals. The membranes/process components are soaked for a period of time then the spent chemical solution is removed from the train. This process may also be termed “clean-in-place (CIP).”
- Q. Relaxation: Any instance a membrane train is taken offline by temporarily stopping the permeate pump.
- R. Small Membrane Subunit: Basic unit of membrane production. The small membrane subunit is the smallest assembled unit of a delivered system that is designed to be removed from a large membrane subunit and replaced as a complete unit. Depending on the MES supplier, this may be a single assemblage of fibers in a common potting attached to a support structure and may be referred to as a “module,” “cartridge,” or other terms.
- S. Temperature Corrected Permeability:
 - 1. Equals permeability multiplied by MES Supplier’s Temperature Correction Factor (TCF) expressed in the following form:
$$P_{20} = P_t \times TCF^{(20-t)}$$

Where:
 P_{20} = permeability at 20 degrees C (Celsius)
 P_t = permeability at measured temperature in degrees C
 t = temperature in degrees C

Unless otherwise provided by MES supplier, TCF shall be 1.024.
- T. Transmembrane Pressure (TMP): The pressure differential across the membrane. TMP shall be adjusted for losses from membrane discharge to pressure gauge. Units of TMP are pounds per square inch (psi).

1.03 SYSTEM DESCRIPTION

- A. MES consists of membranes assembled into Large Membrane Subunits and submerged in mixed liquor in membrane tanks, permeate/backpulse pumps drawing/pushing treated water through membranes, air scour blowers sending air into membrane tanks, chemical dosing systems for membrane cleaning, and appurtenances and control to enable operation of the system to separate treated water from mixed liquor. Large Membrane Subunits will be placed in membrane tanks outdoors in Facility 25. Equipment outside of the membrane tanks is located indoors in Facility 32.
- B. The proposed system by the MES Supplier may require modifications to the current design. Contractor should request sufficient feedback from the MES Supplier to incorporate the system proposed into the design as installed.

1.04 DESIGN REQUIREMENTS

- A. Design of all systems, equipment, and components, including supports and anchorage, shall be in accordance with provisions of the 2018 edition of the Arizona Building Code, and all other applicable local agencies, and the following conditions:
 - 1. Wind: Basic wind speed, V: 115 mph, with Exposure Category C, and Risk Category III.
 - 2. Snow Load: Basic ground snow load, not applicable.

1.05 QUALIFICATIONS AND EXPERIENCE

- A. The manufacturer shall meet the following minimum criteria to be considered qualified:
 - 1. A minimum of five membrane bioreactor installations treating municipal wastewater meeting the following criteria:
 - a. Reference facilities shall be in North America.
 - b. Reference facility shall use the same membrane (material, thickness, pore size distribution, and support) as proposed.
 - c. Reference facility shall use the same small membrane subunit as proposed (fiber diameter, fiber spacing, and surface area).
 - d. In successful continuous operation for no less than 1 year, meeting all effluent requirements and flow capacity requirements for the facility.
 - e. In successful continuous operation for no less than 2 years without replacing membrane modules.
 - f. Minimum design annual average flow of 0.475 million gallons (U.S.) per day.

1.06 SUBMITTALS

A. Submittal required with Contractor's bid:

1. Information to demonstrate compliance with Article Qualifications and Experience, including plant name, location, contact information for plant staff, and details about the MES installed.
2. Exceptions to the Contract Documents.

B. Action Submittals:

1. Following receipt of a purchase order by the MES Supplier from the Contractor, the MES Supplier shall provide six sets of the following general Shop Drawing items to the Contractor. These Shop Drawings shall then be submitted by the Contractor for review by the Contracting Officer and Government:
 - a. Schedule for submittals, fabrication of equipment, delivery, and all onsite activities. Schedule for onsite activities shall detail all required activities for both the MES Supplier and the Contractor, listing durations, prerequisites for activities, etc. The Contractor shall incorporate these activities into the overall construction schedule.
 - b. Anchorage design information including equipment weight, center of gravity, anchor bolt layout, anchor bolt diameter, anchor bolt forces, and other pertinent information required to design the anchorage of the equipment.
 - c. For software, provide narrative description of control system, logic diagrams, summary of control functions, summary of monitoring functions, description of alarms, and other information to describe the control system. Identify specific logic components to be programmed into each PLC.
 - d. Listing of complete scope of supply of equipment, valves, instruments, components, and materials included. Provide the following for pumps, valves, and all other mechanical equipment provided by MES Supplier, including but not limited to, compressors, air separators, etc.:
 - 1) Motor submittal information as required per Section 26 05 02, Basic Electrical Requirements.
 - 2) Complete catalog information, descriptive literature, specifications, and identification of materials of construction. Seal, coupling, and bearing literature shall be included with the pump information.
 - 3) Detailed Mechanical Drawings showing the equipment dimensions, size, and locations of connections and weights of associated equipment.

- e. Overall process flow diagram, calculations, and design data to substantiate selection of equipment and pipe sizing. Provide design flow rates for all systems and subsystems.
- f. Scaled equipment and piping layout drawings in both plan and section. The Drawings shall show the size, type, and locations (with dimensions) of all mechanical and electrical equipment, piping valves, instruments, components and appurtenances within membrane tanks and trains. Identify all external interface connections. Provide clear delineation between equipment, valves, and piping supplied by the MES Supplier, and equipment, valves, and piping supplied by others.
- g. Scaled drawings in sufficient detail to confirm Contracting Officer's design of reinforced concrete tanks, channels, building structures and associated tank cover openings, and lifting devices required for maintenance of the system. Show all system required concrete embeds and identify the size and location of field piping connections to be provided by others. Provide clear delineation between piping, equipment, and materials supplied by the MES Supplier and piping, equipment, and materials supplied by others.
- h. Provide plan, section and detail drawings in electronic form.
- i. Provide air scour requirements in terms of pressure and air flow for various membrane trains in service based on membranes supplied and for various membrane trains in service based on all flow conditions described in Article General System Characteristics, and for the condition with all empty spaces filled with membranes. Provide minimum pressure required at connection to air scour header considering submergence, header, and diffuser losses.
- j. Provide air extraction system pressure and flow requirements at the eductors.
- k. Provide air extraction system pressure and flow requirements at connection to the air separation column of permeate pumps as applicable.
- l. Provide instrument air demands (total flow and pressure) and air quality requirements.
- m. Provide the following Electrical Drawings and Information:
 - 1) List of special motor features being furnished (i.e., space heaters, thermal protectors, etc.).
 - 2) Complete motor rating for all 480V, three-phase motors including motor no-load, starting, and full-load current at rated voltage; full-load speed and full-load current at 100 percent voltage; motor efficiency and power factor at 50 percent, 75 percent, and full load (100 percent) at rated voltage.
 - 3) List any components that will run off power supply other than 480V, three-phase.

- 4) One-line diagram(s) including all transformers, drives, panel boards, meters, and protective devices.
- n. Complete motor nameplate data, as defined by NEMA, motor manufacturer, and including any motor modifications.
- o. Provide the following Instrumentation and Control Drawings and Information:
 - 1) Process and Instrumentation Diagrams (P&IDs) for the system, as per the requirements specified in Section 40 99 90, Package Control Systems. Provide clear delineation between equipment, piping, and components supplied by the MES Supplier, and equipment, piping and components supplied by others.
 - 2) Provide examples of HMI screens that have been provided on previous projects.
 - 3) Provide a block diagram of the proposed control system including the HMI(s), PLC(s), and the data highway.
 - 4) Provide listing of all alarm events and all other events that could cause a membrane train to shut down or to be placed into standby or shutdown or any other nonproducing state.
- p. The MES Supplier shall provide details of the following process areas and equipment on the P&ID drawings as a minimum:
 - 1) Membrane equipment system.
 - 2) Membrane tanks.
 - 3) Membrane permeate pumping system and piping.
 - 4) Membrane air scour blower system and piping.
 - 5) Backpulse pumping system, tanks and piping.
 - 6) Membrane chemical cleaning dosing systems.
 - 7) Compressed air system.
 - 8) P&ID Legend Sheets, as per sample drawings provided.
 - 9) Any other system, which is directly interfaced with the membrane system.
- q. P&ID shall also indicate PLC panel tags to which each component is wired to.
 - 1) Process Control Narratives which define process control concepts and complement the P&IDs. Describe functions monitored, controlled and alarmed.
 - 2) For applications software, provide narrative description of process control systems and overall control system, logic diagrams, summary of control functions, summary of monitoring functions, description of alarms, and other information to describe the control system.
- r. Provide a detailed instrument list for all field instruments including service, type of instrument, make/model number, range, hazardous area classification, and mounting details.
2. Within 45 days after approval of Shop Drawings by the Contracting Officer during construction, the MES supplier shall provide six sets of

the following software Shop Drawings to the Contractor. These Shop Drawings shall then be submitted by the Contractor for review by the Contracting Officer and Government:

- a. Software Description: Provide narrative description of control system, summary of control functions, summary of monitoring functions, description of alarms, and other information to describe the control system.
3. Contractor's proposed method for removal and flushing of the glycerin and for offsite disposal.

C. Information Submittals:

1. The MES Supplier shall submit, through the Contractor, the following items:
 - a. Operation and Maintenance Manuals: Six copies of a draft O&M Manual. Provide 15 days prior to the scheduled delivery of equipment. Six copies of a final O&M Manual, incorporating review comments from the draft manual. Provide in three-ring binders.
2. Executed warranties.
3. MES Supplier's Certificate of Proper Installation.
4. Factory test report for each test and inspection.
5. Field test reports for each functional and performance test of equipment.
6. Data summary from testing and startup period.
7. Three copies of final Operator Interface Unit (OIU) screens commented and documented in electronic format. Provide on CD-ROMs.
8. Three copies of final OIU screens, commented, and documented in hard copy format. Provide in three-ring binders.
9. Three copies of each final PLC ladder logic program fully annotated, commented and documented in electronic format. Provide on CD-ROMs.
10. Three copies of each final PLC ladder logic program fully annotated, commented and documented in hard copy format. Provide in three-ring binders.
11. One copy of the OIU development software and required communications drivers identical to that used by the MES supplier to develop the OIU screens.
12. One copy of the PLC ladder logic programming software and required communications drivers identical to that used by the MES supplier to develop the PLC(s) ladder logic programs.

1.07 GUARANTEE AND WARRANTY

- A. MES supplier shall provide a guaranteed replacement price, as a cost for each large membrane subunit and as a cost per small subunit. Include all costs to deliver membranes to the South Rim WWTP.

- B. MES supplier shall warrant and replace the membranes under warranty for a period of 10 years from the date of Substantial Completion. The warranty shall not be pro-rated. All warranty and support shall be provided directly by the MES supplier and not the local representative.
- C. MES supplier shall warrant the membranes under the following terms:
 - 1. MES supplier shall repair, replace, or add at no cost to the Government, any small membrane subunits that fail before 10 years from the date of Substantial Completion. Testing and warranty will be applied to each train and each large subunit.
 - 2. Failure is defined as any of the following:
 - a. Inability to meet performance requirements as specified herein.
 - b. Inability to meet the interval between cleaning cycles for each membrane cleaning strategy used as specified herein.
 - c. If MES supplier is unable to modify the system through addition of membrane subunits and cannot satisfy requirements of Performance Test, or if system fails to meet specified performance criteria during the warranty period, MES supplier shall be responsible for all costs (including but not limited to labor, professional services, equipment, materials, transportation) needed for complete removal of nonconforming system and subsequent installation of membrane products that meet specified performance conditions.
- D. MES supplier shall guarantee that, for components manufactured by the MES supplier, replacement parts shall continue to be available to the Government for a minimum of 20 years from date of Substantial Completion. MES supplier shall guarantee that, if MES supplier or MES supplier's product line is sold, MES supplier shall make provisions such that all guarantees, warranties, and bonds will remain in effect and that replacement parts and operational support continue to be available to the Government for the time period specified above.
- E. MES supplier shall further warrant all actuated valves for a minimum period of 1 year after Substantial Completion. The warranty shall not be pro-rated.
- F. MES supplier shall warrant all other equipment, not specifically mentioned above, against defects in workmanship and materials for a period of 1 year. The warranty period shall begin following Substantial Completion. The warranty shall not be pro-rated.
- G. MES Supplier shall make all repairs or replacements necessitated by defects in materials or workmanship that become evident within the warranty period. The repair or replacement shall start not later than 10 days after Government notifies the MES Supplier and shall be completed to Government's

satisfaction not later than 30 days after the notification to the MES Supplier was first issued.

- H. MES Supplier also agrees to hold the Government harmless from liability of any kind arising from damage due to defects of equipment/system supplied by MES Supplier. MES Supplier shall make all repairs and replacements promptly upon receipt of written orders for same from the Government. If within 10 days after the Government has notified MES Supplier of a defect, MES Supplier has not started to make the necessary corrections or has not completed the corrections to Government's satisfaction within 30 days after Government has notified MES Supplier of a defect. The Government is hereby authorized to make the corrections or to order the Work to be done by a third party, and the cost of the corrections shall be paid by MES Supplier and warranty remains in effect.
- I. Any material and equipment that fails (as defined above) more than twice or cannot be restored to meet the design capacity and performance by chemical cleaning and backwashing within 30 days of the date Government first notifies MES Supplier of the failure shall be cause for material and equipment replacement and an extension of the warranty period for the specific component(s) to a date 2 years following acceptable replacement.

1.08 SPARE PARTS AND SPECIAL TOOLS

- A. Provide the following spare parts, at a minimum, in addition to manufacturer's standard spare parts and recommended special tools:
 - 1. One set of expendable materials such as gaskets, seals, and packing.
 - 2. One set of new and unused special tools required for installation, operation, and maintenance per each type of equipment or system.
 - 3. One repair kit for sealing off damaged membrane fibers within the small membrane subunit sufficient to repair up to 5 percent of the supplied membranes.
 - 4. One complete set of all jigs, fixtures, clamps, lifting beams, hooks, and other instruments required facilitating the removal, disassembly, reassembly, and installation of each item of equipment within the system.
 - 5. Reagents/chemicals, calibration sets, and spare parts as specified for individual equipment items or instruments.
 - 6. Spare parts for instruments, PLC hardware and control devices as specified in Section 40 99 90, Package Control Systems.
 - 7. Extra materials for related equipment as specified in Section 44 42 19.04, Rotary Positive Displacement Blower, Section 44 42 56.14, Lobe Pumps, and Section 43 40 01, Polyethylene Storage Tank.
 - 8. One shelf spare permeate pump, each size.

9. One shelf spare for each type of meter (flow, level, etc.), pressure gauge, pressure differential transmitter, valve and actuator supplied under this Contract.
 10. Any additional special tools and spare parts recommended for the first year of operation.
- B. Guarantee availability of manufacturer's standard spare parts, those required above, and recommended special tools for a period no less than 20 years.

PART 2 PRODUCTS

2.01 GENERAL SUPPLY AND SCOPE

- A. MES Supplier shall furnish the subsystem components listed below in accordance with the requirements of the project specifications and Contract Documents. All components shall be shipped loose for installation by installing Contractor unless otherwise noted.
1. Membrane Tanks:
 - a. Large Membrane Subunits.
 - b. In-basin interconnecting air and permeate piping
 - c. Permeate header piping and valves terminating with a permeate header connector outside of the membrane tank.
 - d. Air header piping and valves terminating with an air header connector outside of the membrane basin.
 - e. Membrane support brackets. Either guide rails when supported off the floor or beam assemblies when supported from the top of the basin.
 - f. Pipe supports and support anchors for all Supplier-provided piping. Anchor bolts shall be provided by Contractor.
 - g. Basin level switches and level transmitters.
 2. Permeate Collection System:
 - a. Permeate pumps.
 - 1) Permeate pump VFDs.
 - b. Membrane permeate process instrumentation.
 - c. Membrane permeate turbidity meters, one per train and one on the combined permeate.
 - d. Membrane permeate air ejector assembly and associated pipes and pipe connects, one per train.
 3. Membrane Cleaning Systems:
 - a. Skid-mounted chemical metering pumps, actuated valves, and instrumentation.
 - b. Chemical injection assemblies to the cleaning chemical injection points on the permeate pipe, one set including sodium hypochlorite and citric acid injection per train.

- c. Backpulse tank with tank vent, drain, and flanges.
 - 1) Top mounted ultrasonic level sensor with transmitter.
 - 2) Level switches, high and low.
 - d. Actuated valves, one per train on permeate production, one per train on backpulse supply, and one for the backpulse tank feed.
 - 4. Membrane Air Scour System:
 - a. Scour air blowers capable of providing required air with one of the blowers offline.
 - b. Scour air instrumentation.
 - c. Actuated valves, one per train, on air scour air supply pipes.
 - d. Flow switch, one per blower, to detect air flow.
 - 5. Membrane Equipment System Control:
 - a. MES control panel.
 - b. MES operator interface.
 - c. PLC programming.
 - d. Compressed Air System for pneumatically actuated valves and air ejectors.
- B. Large Membrane Subunits and equipment shall be prefabricated, preassembled, and factory tested before shipment to the Site.
- C. MES Supplier shall provide the Equipment as described in these Specifications:
 - 1. Equipment shall be new and unused and shall meet the qualification requirements described in Action Submittals of this section.
 - 2. Equipment shall be furnished as a complete, operable, and maintainable system including all instruments, devices, valves, and actuators.
 - 3. Equipment shall fully comply with the stricter of Arizona and Federal OSHA standards.
- D. All components of the MES shall be fully automated as described in the Contract Documents as the system may be unstaffed for the majority of time. Recovery cleaning operations shall be automated but may be operator initiated.
- E. All components of the MES shall be tagged to conform with Contracting Officer's tag numbering convention. Where applicable, use Contracting Officer provided tag numbers as shown on the Drawings and listed in Specifications.

2.02 WORK BY CONTRACTOR

A. The following items are supplied by Contractor:

1. Structural:
 - a. Building(s) or cover for housing membrane equipment.
 - b. Concrete tankage for membrane trains.
 - c. Imbedded wall spools in concrete tank walls for the various process pipe connections.
 - d. Covers or grating over membrane trains, including support of covers/grating.
 - e. Equipment access platforms, walkways, stairs, etc.
 - f. Protective coatings for concrete, if necessary.
 - g. Anchor bolts for membrane equipment.
2. Mechanical:
 - a. Permeate piping past the edge of the membrane tank.
 - b. Air piping past the edge of the membrane tank.
 - c. Cleaning chemical supply piping with double-contained pipes.
 - d. Pipe supports and hangers, not contained within the membrane tank, unless otherwise noted.
 - e. Hoist equipment above the membrane tank for installation and removal of the membrane subunits.
 - f. Single connection points, unless otherwise noted, for each membrane train for the following:
 - 1) Permeate header.
 - 2) Air scour header.
 - g. Installation materials for instrumentation and automatic valves including, but not limited to, air/sample line tubing, fittings, and mountings.
 - h. Return activated sludge (RAS) pumps.
 - i. Sludge wasting systems (pipes, valves, pumps).
 - j. Containment for chemical storage totes.
 - k. Bulk Chemicals for maintenance and recovery cleans.
 - 1) Sodium hypochlorite (12.5 percent by weight concentration).
 - 2) Citric acid (50 percent by weight concentration).
 - 3) Other chemicals as required by MES Supplier.
 - l. Bulk chemical storage tanks and chemical day tanks including spill containment.
 - m. Backwash tank(s), if required.
 - n. Gates or valves and control elements for mixed liquor influent and effluent.
3. Electrical:
 - a. Electrical wiring interconnections (including wiring, conduit and other appurtenances required to provide power and control

- connections as needed) from the electrical power source or control devices to the membrane PLC control panel.
- b. Electrical wiring interconnections (including wiring, conduit and other appurtenances required to provide power connections as needed) from Membrane System PLC or motor control centers to the membrane system motor driven equipment.
- c. Instrumentation and control wiring, conduit and other appurtenances required to provide connections as needed between the terminal of membrane equipment, pumps, instruments etc., and the membrane PLC control panel.
- d. Motor control centers, VFDs, panel boards, transformers, and other equipment necessary to provide power distribution and control for all equipment except for the permeate pump VFDs.
- e. Ethernet communications connection to the Government's Plant Control System/SCADA and Membrane Master PLC.
- 4. Other:
 - a. Receiving, unloading and safe storage of equipment at site or a storage facility until ready for installation.
 - b. Equipment installation.
 - c. Raw materials, chemicals and utilities during equipment testing.
 - d. Laboratory services, operating and maintenance personnel during equipment checkout, startup and operations.
 - e. Onsite painting or touchup painting of membrane equipment, with the exception of painting required due to damage incurred prior to equipment being received onsite.

2.03 MANUFACTURERS

A. The MES shall be supplied by and use membranes manufactured by:

- 1. Veolia, Oakville, Ontario, Canada.
- 2. Or equal.

2.04 GENERAL SYSTEM CHARACTERISTICS

A. Physical Characteristics:

- 1. Membrane Tank Configuration:
 - a. Three membrane tanks will be constructed by Contractor. Each tank will have a dedicated permeate pump and return activated sludge (RAS) pump (pumping from membrane tank to bioreactors). The number of membrane subunits within each tank to be provided and the equipment to be installed shall be determined by the MES Supplier.
 - b. Each membrane tank will be 10 feet 6 inches wide, 8 feet long, and no deeper than 14-1/2 feet deep of wall height. Minimum

freeboard for the membrane tank during normal operation shall be 3 feet. The large membrane subunit(s) and all associated equipment shall fit in this tank size.

c. The depth of the membrane tank shall be determined by the MES Supplier.

2. Equipment shall fully comply with OSHA standards.

B. Functional Characteristics:

1. Each MES train shall include an online turbidimeter on the permeate line.
2. The MES shall utilize rotary lobe pumps capable of reversing the flow direction for backpulse and membrane cleaning purposes.
3. Mixed liquor from the biological treatment system will be introduced to the membrane tanks via a weir gate by gravity, and RAS will be pumped from the membrane tanks to the biological treatment system.
4. RAS will be extracted from the bottom of each membrane tank, and RAS pumps will be used to drain the membrane tank when necessary.

C. Performance Characteristics:

1. Electrical material and equipment shall have UL listing wherever standards have been established by that agency. Complete electrical assembly shall meet requirements of NEC, NEMA, and NFPA.
2. Influent wastewater will be screened using 1 millimeter screens. No bypass of the screens will be permitted in any direction. The 1 millimeter fine screens will be preceded by a 6 millimeter screen and a conventional grit removal system. Screening and grit systems shall be provided by others. A portion of the return activated sludge may be reintroduced upstream of the fine screens.
3. Biological reactor zones will be provided upstream of the MES and furnished by others. Membrane tanks to place the large membrane subunit will be provided by Contractor. The MES will provide filtration for mixed liquor from a biological wastewater treatment process.
4. The MES performance requirements specified herein shall be met when mixed liquor characteristics comply with the following:
 - a. The biological treatment system is designed to maintain nitrification (bioreactor effluent ammonia nitrogen less than 1 mg/L) and denitrification (bioreactor effluent nitrate nitrogen less than 10 mg/L). Supplemental carbon may be added for denitrification.
 - b. Effluent Alkalinity: Greater than or equal to 100 mg/L. Effluent pH range goal is 7.0 to 8.3. Magnesium hydroxide is added to bioreactor influent for alkalinity and pH control.
 - c. Ferric chloride or other coagulant may be applied to the biological treatment system for effluent copper limit compliance.

5. Other Operating Conditions:

Parameter	Units	Off-season	In-season
Site elevation	ft	6,700	
Ambient temperature	°F	-18 to 95	
Relative humidity	%	20 to 77	
Minimum 30-day average process temperature	°C	11	15
Seasonal average process temperature	°C	14	20
MBR process solids retention time (minimum)	days	15	13
Mixed liquor suspended solids (entering membrane tanks)	mg/L	6,300	8,300
Maximum RAS flow per membrane tank	gpm	900	900
Time to filter (TTF) (weekly average)	seconds	≤ 200	≤ 200
Ammonia-nitrogen leaving oxic zone (monthly average)	mg/L	≤ 1.0	≤ 1.0

6. Membrane permeate pumps, air scour blowers, and compressors will be located indoors.

D. MES System Performance Requirements:

1. Design Flows:

- a. Design the MES for 2045 requirements with ability to add membranes to meet 2070 requirements. Add 40,000 gpd to each influent flow rate in the following table to obtain the net membrane filtrate design flows. Peak flows could occur at any time of year.

Flow Condition	Units	2045		2070	
		Off-Season	In-Season	Off-Season	In-Season
Seasonal average (1)	gpd	420,000	430,000	450,000	540,000
Maximum 30-day average (2)	gpd	500,000	515,000	540,000	645,000

Flow Condition	Units	2045		2070	
		Off-Season	In-Season	Off-Season	In-Season
Maximum day (3)	gpd	830,000	830,000	970,000	970,000
Sustained peak (4)	gpd	1,180,000	1,180,000	1,180,000	1,180,000
(1) Off-season is October-March. In-season is April-September. (2) Duration of maximum 30-day flow is 30 days. This condition occurs once per season. (3) Maximum day flow after equalization. Duration of maximum day flow after equalization is 24 hours. This condition occurs undefined number of times per season. (4) Sustained peak flow after equalization. Duration of sustained peak flow after equalization is 6 hours. This condition occurs an undefined number of times per season.					

- b. It is intended that all membrane trains will be in service under normal operating conditions. The MES shall be capable of meeting all performance requirements stated herein under the average and maximum month flow conditions with one membrane train out of service, and under the maximum day and sustained peak flow conditions with all trains in service. The out of service train can be used for tank maintenance or membrane recovery cleaning. When one membrane train is out of service, maintenance cleaning of another train will be performed during a low-flow time of day or by using the plant's equalization tank.
 - c. Raw wastewater flow to the treatment facility is expected to follow normal diurnal wastewater flow patterns. Influent diurnal minimum flows may be 15 percent to 25 percent of the daily average flow. Permeate flow may be intermittent for influent flows less than the turndown of one permeate pump.
2. The supplied MES shall meet all of the membrane permeate quality requirements in Paragraph Membrane Permeate Quality, and operate at normal operating parameters and conditions at the production capacities in Paragraph Design Flows.
 3. The MES Supplier shall determine the required membrane surface area to meet the performance requirements and warranty provisions and provide the membrane tank dimensions for each membrane train, including required clearance between the tank inlet and large membrane subunits and between large membrane subunits and tank outlet. Include provision to increase membrane surface area to meet the 2070 design condition. During the course of the design, initial operation, warranty period, or during the course of the repair and replacement contract, if the MES Supplier determines that additional volume is required, MES Supplier shall pay all costs for constructing the additional volume.
 4. Design production capacity will be verified by the Government and Contracting Officer, during the Performance Acceptance Test and

Commissioning and during the subsequent membrane guarantee and warranty period. Compliance is required for each membrane train. The MES Supplier, to Government's satisfaction at no additional cost to the Government, is responsible for modifying the system during startup and within warranty period to achieve design production capacity if testing of membrane system fails to meet the design production capacity.

5. Membrane Permeate Quality:
 - a. Membrane permeate shall meet the ADEQ requirements and the following, which may occur at any time:
 - 1) Turbidity: Shall not exceed 0.2 NTU more than 5 percent of the time within a 24-hour period and shall not exceed 0.5 NTU at any time.
 - 2) Turbidimeter shall have a signal averaging time not exceeding 120 seconds.
6. Membrane Cleaning:
 - a. Membrane subunits shall be cleaned in place using backwash, chemical solutions, or relaxation to meet production capacity and other performance requirements specified herein.
 - b. Maintenance cleans shall not be performed more frequently than twice per week using sodium hypochlorite and once per week using citric acid.
 - c. Recovery cleans shall not be performed more frequently than once every 90 days.
 - d. Cleaning chemical consumption shall not exceed the following annual average amounts:
 - 1) Sodium Hypochlorite: 850 gallons of 12.5 percent solution by weight.
 - 2) Citric Acid: 630 gallons of 50 percent solution by weight.
7. Polymer Addition: MES Supplier shall not be permitted to add polymer to increase operating flux or for any other performance improvements.
8. Transmembrane Pressure:
 - a. TMP at peak flow shall not exceed the value demonstrated at any of the reference projects provided in the submittal required with Contractor's bid.
 - b. TMP at peak flow after chemical cleaning shall not exceed 3.5 psi.
9. Air Scour:
 - a. Air scour for the MES shall not exceed the rates shown on the following table:

Flow Condition	Airflow per Tank (scfm)
Seasonal average	97
Maximum 30-day average	97
Maximum day	195
Sustained peak	195

2.05 MEMBRANE COMPONENTS

A. Physical Characteristics:

1. Membrane Material: Use polyvinylidene fluoride (PVDF) hollow fiber membranes, having a nominal pore size of 0.04 micron or less.
2. Small Membrane Subunits:
 - a. The membranes shall be assembled into a housing defined in this specification as a small membrane subunit.
 - b. The small membrane subunit shall be constructed such that the membranes are held vertically and bonded firmly at the top and bottom.
 - c. The internal lumens of the membrane fibers shall connect into a common area at the top and bottom of each small subunit.
 - d. The top and bottom sections of the small membrane subunit shall be connected with corrosion resistant materials and allow permeate to be withdrawn from both ends of each small membrane subunit.
3. Large Membrane Subunit:
 - a. The small membrane subunits shall be assembled into large membrane subunits.
 - b. Each large membrane subunit shall be supported within a frame or support rails manufactured of chemically resistant Type 316L stainless steel materials, or other materials provided the proposed assembly has been successfully used by the MES Supplier for at least 2 years.
 - c. Provide a complete support system for installation in concrete basin, consisting of beams, frames, and brackets. Anchor bolts shall be furnished by Contractor.
 - d. Fit each frame with two lifting eyes (one at each end) to allow the entire large membrane subunit to be lifted into and out of the membrane tank and transported away. A lifting bracket that connects to the frame at multiple points and is lifted at one point is also acceptable.
 - e. All fasteners, including nuts, bolts, screws, cables, washers, and other appurtenances, associated with the large membrane subunit and housing shall be manufactured from Type 316 stainless steel. MES Supplier shall ensure that sufficient isolation is provided such that no galvanic corrosion occurs between fasteners and the frame/support rails.

B. Functional Characteristics:

1. Membrane Material: Flow from the outside to the inside of the fiber during production of permeate.
2. Small Membrane Subunit: The base of each small membrane subunit shall use diffusers to allow scour air to escape and travel upwards past and between the membrane fibers, creating an agitation effect.
3. Large Membrane Subunit: None.

C. Performance Characteristics:

1. Membrane Material:
 - a. Membranes shall be constructed of chemically resistant materials as required for stipulated range of operating and maintenance conditions. Membranes shall be capable of being washed in high chlorine solutions (minimum 1,000 mg/L), and low pH (range 2 to 3) and high pH wash solutions (range 10 to 11).
 - b. Membranes shall be physically strong enough to withstand the operating conditions associated with continuous operation in a membrane tank of mixed liquor at concentrations of up to 15,000 mg/L.
 - c. For systems which use backpulsing and chemical cleaning, membranes shall be able to withstand backwash flow (from inside to outside) as proposed by MES Supplier without any damage.
2. Small Membrane Subunit:
 - a. The materials used to hold the membrane fibers in place shall be chemical resistant to high concentrations of chlorine (minimum 1,000 mg/L), and low pH (2) and high pH (11) wash solutions.
 - b. All non-steel components of the small membrane subunits shall be UV resistant and have a chemical resistance at least equal to that of the membranes.
 - c. Large Membrane Subunit: None.

2.06 PERMEATE PUMPING SYSTEM

A. Physical Characteristics:

1. Permeate Suction Piping: Each membrane train shall have a suction header for permeate collection. The header shall have a connection for a pressure/vacuum gauge at each end.
2. Permeate Pumps:
 - a. Pumps shall be reversible rotary lobe pumps in accordance with Section 44 42 56.14, Lobe Pumps.
 - b. Quantity: One dedicated pump per membrane train and as required in Article Spare Parts and Special Tools.

- c. Pumps shall meet the reverse flow requirement for the backpulse operation at sufficient flow rate to meet backpulse flux no less than 20 gallons per square foot per day, or as required by the MES Supplier.
 - d. Coordinate permeate pump system with relaxation and backpulse schedule. Minimize the time with no forward flow into the UV disinfection process.
 - e. Coordinate permeate pump system for low flow conditions where permeate pumps may operate intermittently to minimize the time with no forward flow into the UV disinfection process.
3. Air Extraction System (if required): The system shall consist of an eductor mounted to the high point of permeate piping system, level sensors, and control valves unless otherwise required by the MES Supplier. Eductor shall utilize instrument air. Air extraction systems that rely upon water-driven eductors or vacuum pumping are unacceptable.

B. Functional Characteristics:

- 1. The permeate suction pipe connections between the large membrane subunits and the header pipe work shall be capable of operating at the positive and negative pressures expected for this system.
- 2. Air Extraction System (if required): An air extraction system shall be provided to prime the permeate headers and to remove air bubbles generated during the permeate extraction process.
- 3. Air Separation Column (if required):
 - a. MES Supplier shall size column to provide adequate residence time to ensure satisfactory air removal from the permeate.
 - b. Column shall be Type 316 stainless steel.
 - c. Provide one column per membrane train.
 - d. The air outlet of the air separation column eductors and/or control valves shall be connected to a drain with piping provided by others.
 - e. Each air separation column shall be equipped with a level sensor. Apart from normal operating control loops, the level sensor will include a Level-Alarm-Low level. Should the liquid level in the vessel drop to this level, an alarm will be generated.

C. Performance Characteristics:

- 1. Rated Capacity: Rated capacity of permeate pumps shall be sufficient for all specified operating conditions. The amount of permeate water used for membrane cleaning shall be taken into account when determining the rated capacity of the permeate pumps.
- 2. The permeate pump shall deliver a total dynamic head of 45 feet of water at all specified operating conditions.

2.07 COMPRESSED AIR SYSTEM

A. Physical Characteristics:

1. Compressed air system shall include:
 - a. 1+1 reciprocating compressors.
 - b. Air filters.
 - c. Air dryers.
 - d. Air receivers with a drain.
 - e. Piping and appurtenances within the air compressor package.
2. Air compressor will be placed in Facility 32, blower room.
3. Mount motor and compressor on common steel base attached to receiver.
4. Compressor connected to motor by V-belt drive system with guard, and convenient method of belt tensioning.
5. Equip with combination air intake filter silencer, oil filter, and discharge cushion chamber.
6. Motor:
 - a. In accordance with NEMA MG 1.
 - b. Type: Squirrel-cage.
 - c. Frequency: 60 Hz.
 - d. Service Factor: 1.15
7. Receiver:
 - a. Volume: MES Supplier is responsible for determining the receiver volume.
 - b. Horizontal welded steel receiver bearing ASME code stamp and with inspection openings.
 - c. Pressure gauge with gauge cock.
 - d. Pressure safety valve.
 - e. Automatic condensate drain valve with isolation valve.
 - f. Manual blowdown valve located at low point in receiver.
 - g. Corrosion Allowance: 1/16 inch.
8. Control Panel: Mount in accessible location on receiver.
 - a. Enclosure:
 - 1) NEMA 250, Type 12 panel for indoor installation to house complete control system including:
 - a) Control power transformer.
 - b) HAND/OFF/AUTOMATIC switch.
 - c) Pressure switches.
 - d) Relays.
 - e) System pressure indicator.
 - f) Indicating light(s).
 - g) Combination motor starter (NEMA Size 1 minimum) with overload protection.
9. Prewired Control Components: Operate on 120V ac power supply.
10. Power Supply: 480 volts, three-phase, 60 Hz.

- B. Functional Characteristics: Provide compressed air for instrument air to operate eductors, pneumatic valves, and any other instrumentation of the MES Supplier's equipment package requiring compressed air.
- C. Performance Characteristics:
 - 1. MES Supplier is responsible for determining the capacity, operating discharge pressure, and motor horsepower.
 - 2. Controls:
 - a. ON/OFF cyclic operation.
 - b. Automatic low oil pressure shutdown with indicating light and oil pressure gauge.

2.08 AIR SCOUR SYSTEM

- A. Physical Characteristics:
 - 1. Provide air scour blower system including blowers, controls, valves, inlet filters, check valves, pressure gauges, discharge pressure safety valves, low flow switches, and high pressure switches as required by MES Supplier for control of fouling and to assist in keeping the mixed liquor in a membrane tank in suspension.
 - 2. Blowers shall be positive displacement type in accordance with Section 44 42 19.04, Rotary Positive Displacement Blower. Size blowers for water surface depth at top of membrane tank wall. Provide one of the following configurations:
 - a. Dedicated Blower: Each train has a dedicated blower. Provide a minimum of one shelf spare blower.
 - b. Common Header: Provide a minimum of two duty blowers and one standby blower with all membrane trains in service. Provide control and measurement of flow to each individual train.
- B. Functional Characteristics:
 - 1. Air cycling valves and actuators, if required for control and operation of the air scour to each membrane train and large membrane subunit.
 - 2. Provide air distribution header(s) and diffusers for each membrane train within limits of the membrane tank.
- C. Performance Characteristics:
 - 1. MES Supplier is responsible for determining the capacity and discharge pressure.
 - 2. MES Supplier is responsible for specifying the VFD, to be provided by Contractor, and designing the air flow control system.

2.09 CLEANING SYSTEMS:

A. Physical Characteristics:

1. Backpulse System:

- a. Provide backpulse tank, isolation valves, check valves, flow meters, instrumentation and controls, and other components to provide an automated backwash system.
- b. Backpulse tank shall be off-line from the permeate pipe transferring permeate to the reclaimed water tank through the in-vessel type UV disinfection process, with an actuated valve controlled by the backpulse tank water level switches to maintain water level in the tank while maintaining water pressure to transfer permeate through the UV disinfection process to the reclaimed water clear well, as noted in Article Permeate Pumping System.
- c. Backpulse water will be provided to a large membrane subunit undergoing backpulse, maintenance clean, or recovery clean, through a dedicated permeate pump in reverse flow.
- d. Backpulse water source shall be the permeate produced from the membrane system.
- e. Backpulse tank shall be a high-density polyethylene (HDPE) tank in accordance with Section 43 40 01, Polyethylene Storage Tank, and in sufficient volume to provide one maintenance cleaning while one of the three trains is out of service.
- f. Backpulse tank shall be equipped with level switches (High, Low), and a level sensor.

2. Maintenance and Recovery Cleaning Systems:

- a. Provide the chemical cleaning system with controls for membrane trains with sodium hypochlorite and citric acid:
 - 1) Skid mounted chemical metering pumps, valves and operators, flow meters, instrumentation and controls, and appurtenances for a complete operable chemical feed system shall meet requirements described in Section 44 44 13.01 Chemical Metering Pumps.
- b. Recovery Clean System: RAS pump can be used to drain the membrane tank if recovery clean requires membrane tank to be drained of mixed liquor.

B. Functional Characteristics: Provide a standby pump for each chemical metering pump system.

C. Performance Characteristics:

1. Maintenance Clean is designed to maintain design production capacity by reducing TMP and increasing permeability by oxidizing or

solubilizing biological and nonbiological matter on the membrane surface and within the membrane pores.

2. Recovery Clean is designed to remove solids that have accumulated in small membrane subunits (including on membrane surface and within membrane pores) so that the TMP directly following the cleaning does not exceed 3.5 psi. If the TMP is not restored within the acceptable range after recovery clean following the MES Supplier's procedure, the MES Supplier shall provide guidance for trouble shooting.

2.10 MEMBRANE INTEGRITY TEST SYSTEM

A. Physical Characteristics:

1. Provide continuous turbidity monitoring and alarm system on each train to identify loss of membrane integrity.
2. Provide continuous turbidity monitoring and alarm system on the combined permeate pipe to identify loss of membrane system performance.

B. Functional Characteristics: Provide the method and means to identify the large membrane subunit, small membrane subunit, and individual fibers with loss of membrane integrity.

C. Performance Characteristics: None.

2.11 PIPING AND VALVES

A. Physical Characteristics:

1. MES Supplier's scope of piping supply shall be within the limits of the membrane tank, skid-mounted pumps if provided, compressed air supply system, and skid mounted chemical systems.
2. MES Supplier shall provide permeate headers, air headers, and any other piping and valves required to connect the large membrane subunits to the headers.
3. MES Supplier's scope of valve supply shall include those within the limits of the membrane tank and isolation valves, check valves, control valves, and other required valves outside of the membrane tank for the following systems:
 - a. Permeate Pumping System.
 - b. Air Extraction System.
 - c. High Pressure Compressed Air System.
 - d. Cleaning Systems.
 - e. Membrane Integrity System.
 - f. As specified.

B. Functional Characteristics:

1. Terminal point connections shall be ANSI standard flanges.
2. Piping shall be in accordance with Section 40 27 00, Process Piping—General:
 - a. Install true union fittings where future disconnection may be required.
 - b. Permeate piping shall be designed to limit maximum flow velocities to 8 feet per second (fps). If unable to meet 8 fps flow criteria, MES Supplier shall indicate and describe locations where velocities exceed this limit and rationale as to why they cannot meet the flow criteria.
 - c. Process air piping shall be designed to limit maximum flow velocities to 3,800 feet per minute (fpm). If unable to meet 3,800 fpm flow criteria, MES Supplier shall indicate and describe locations where velocities exceed this limit and rationale as to why they cannot meet the flow criteria.
3. Valves shall be in accordance with Section 40 27 02, Process Valves and Operators.
 - a. Provide all valves required for a completely functional system (shipped loose) within the limits of the membrane tank and for those systems outside the limits of the membrane tank described in Article Piping and Valves.
 - b. Provide valves suitable for intended service and relevant chemical exposure.
 - c. Provide valves to isolate each large membrane subunit. Use of quick-connect caps on the connections to a removed unit is also acceptable.
4. Actuators shall be in accordance with Section 40 27 02, Process Valves and Operators:
 - a. Electric Actuators: Use for typical OPEN/CLOSE application except as noted below.
 - b. Pneumatic Actuators: Use for OPEN/CLOSE application where fast action is required.
 - c. Both electric and pneumatic actuators shall have LOCAL and REMOTE control features. Where integral controls on the actuators are not provided or not accessible, provide Local Controls Stations (LCS) remote from the actuator.

C. Performance Characteristics: None.

2.12 ELECTRICAL

A. Physical Characteristics:

1. Electrical components shall be provided in accordance with Section 26 05 02, Basic Electrical Requirements.
2. Three-phase, 480V ac power shall be available at the Project Site.
3. Pre-piped and skid mounted components shall be prewired to a terminal junction box located on the skid.
4. Electrical material and equipment shall have UL listing wherever standards have been established by that agency.

B. Functional Characteristics: None.

C. Performance Characteristics: Complete electrical assembly shall meet all requirements of the National Electrical Code, the National Electrical Manufacturers Association (NEMA), the National Fire Protection Association (NFPA), and all applicable state and local codes.

2.13 CONTROL SYSTEM

A. Physical Characteristics:

1. All control panels and enclosures shall be in conformance with Section 40 99 90, Package Control Systems, requirements.
2. Provide control panels, PLC and Operator Interface Unit (OIU) hardware and software, data transfer and graphic emulation support, Membrane Control System software package, data links with the Government's Plant Control system, graphic display and configuration, and instruments. Instrumentation and control components shall be in accordance with Section 40 99 90, Package Control Systems.
3. Provide and program PLC and Operator Interface software to control the operation of the MES.
4. Provide and configure PLCs and OIUs per the requirements specified herein and also to support a safely operating system.
5. PLC I/O signals will be distributed across I/O modules to ensure that a single module failure will not eliminate key functionality required for the MES. PLC I/O for membrane trains will be distributed accordingly.
6. The PLCs shall communicate with the Plant Control System via Ethernet network. The Plant Control System shall monitor and provide supervisory control of the MES PLC system. This is in addition to concurrent monitoring and control by each local Operator Interface furnished by the MES Supplier. See below for more details.
7. Provide graphical displays to monitor and control all aspects of MES.
8. Refer to Section 40 91 00, Instrumentation and Control Components, for additional requirements.

9. Refer to Section 40 99 90, Package Control Systems, for additional requirements.
10. PLC Configuration:
 - a. PLC Architecture: Provide one spare PLC, fully programmed with PLC program. The PLC shall be the same make and model as the one furnished for the Project. Furnish an additional PLC (as described above) for each type of PLC on the Project.
 - b. Provide redundant Large-Package PLC, per Section 40 99 90, Package Control Systems, for the membrane system Master PLC.
 - 1) Each PLC controller shall have enough data memory to store twice the amount of tag data that is associated with a redundant controller project, plus an additional 25 percent spare capacity.
 - 2) Train PLCs shall follow either Large-Package PLC or Small-Package PLC, per Section 40 99 90, Package Control Systems. Vendor may opt to not provide Train PLCs and use Remote I/O per train. Remote I/O will follow Large-Package PLC standard.
 - 3) Connect remote train PLCs via Ethernet/IP Device Level Ring network. Implement this network independent from the Ethernet/IP network for connection to the Plant Control System. MES Supplier will work with Contracting Officer to ensure fiber optic ring topology is dedicated for this PLC communication.
 - 4) OIU Supplier and Product: Provide OIU at the Master PLC panel to meet the function description and to interface with the Plant Control System. Refer to Section 40 99 90, Package Control Systems, for additional requirements.
 - c. All motor control starters and VFDs shall be connected to the Master PLC panel via Ethernet/IP Device Level Ring topology. MES Supplier will provide separate and isolated network components for motor control and monitoring. There will be no direct connection between the network to Plant Control System and the motor control network.
 - 1) Contractor shall provide motor control starters and VFDs consistent with plant standards. MES Supplier shall coordinate with contractor to create a working motor control network.
 - d. Equipment and components associated with each membrane train shall be controlled by a sufficient number of PLCs, communication and I/O modules such that the failure of any one component shall not reduce membrane system capacity or functionality.
 - e. Provide all PLCs, chassis and I/O modules as required to support the MES plus a minimum of 20 percent spare. All I/O shall be

- wired to field terminations, isolation and interposing relays for discrete inputs and outputs.
- f. Equipment servicing more than one membrane train, such as backpulse pumps and air compressors, shall have their controls distributed among the Master PLC I/O modules. Assign one equipment unit to a PLC chassis, e.g., one backpulse pump to a PLC chassis such that failure of a PLC module shall affect only one equipment unit in a parallel set of equipment items.
 - g. Control functions required to coordinate the operation of individual membrane trains shall be implemented in a Master PLC with redundant processors. Examples of master control functions include:
 - 1) Allocation of flow set points to each membrane train.
 - 2) Coordinating backwash of each membrane train.
 - 3) Coordinating chemical cleaning of each membrane train.
 - 4) The redundant master PLC processors shall function as “hot backups” such that on failure of the active processor, the control functions shall automatically continue to be performed by the backup redundant processor.
 - 5) All information displayed on the MBR Master PLC panel OIU shall be communicated via Ethernet/IP to the plant SCADA system.
11. Coordination and Data Integration with Plant Control System:
- a. The Plant Control System uses GE iFix application software. This software will be provided outside the scope of the MES Supplier, but will be used as the Plant Control System interface to the membrane system and Master PLC.
 - b. Complete operation of each membrane train shall be possible at the OIU at each train or at the Plant Control System/SCADA HMI graphical screen. The MES Supplier shall assist the Contractor in programming the SCADA HMI computer. Provide for Government and Contracting Officer input into graphics, displays, etc.
 - c. In addition to the Membrane System Operator Interface Units, the treatment process shall have the ability to be operated and monitored from the Main Control Room via the Plant Control System network. MES Supplier shall provide all program files for the PLCs and Operator Interface Units at the completion of the project. MES Supplier shall also provide the graphics files and memory maps of all registers for control and monitoring of the MES such that the Government's Control System Integrator can configure the Plant Control System HMI (Human-Machine-Interface).
 - d. See also requirements in Section 40 99 90, Package Control Systems.

12. All controls and monitoring shall be accessible by the Plant Control System via the Ethernet network. Provide means for data exchange with Plant Control System as specified.
13. Both 120V “normal” power and 120V UPS backed power shall be provided to the Membrane System PLC by Others.

B. Functional Characteristics:

1. The Membrane Control System shall be designed to perform the following functions as a minimum:
 - a. General:
 - 1) Communicate all data to the Plant Control System for monitoring, control, alarming, historical storage (historical trends, alarm logs, operating data, cleaning and backwash information).
 - 2) Provide other features as required by system for unattended operation, unattended startup, and to meet specified performance requirements.
 - 3) Upon loss of communication between the Plant Control System and the Membrane Control System, each train shall continue to operate using, as a minimum, the current permeate flow set point.
2. Permeate System:
 - a. Monitor operational data for permeate and other membrane system components including the following at a minimum:
 - 1) Transmembrane (vacuum) pressure while permeating.
 - 2) Transmembrane pressure while backpulsing (if applicable).
 - 3) Permeate production rate per train.
 - 4) Total (system) permeate production rate.
 - 5) Hours of operation for each permeate pump/train.
 - 6) Permeate temperature for combined permeate flow.
 - 7) Permeate turbidity for each train.
 - 8) Perform calculations of permeability and temperature corrected permeability for each train and plot both parameters as a function of run time.
 - b. Provide trend displays for each train showing the most recent operational data at the current 24-hour flow, 7-day flow, and 30-day flow.
 - c. Permeate Pumps:
 - 1) START/STOP and flow control of permeate pumps.
 - 2) Adjust total permeate production rate through membrane train in response to Total Bioreactor Influent flow and adjusted to maintain a Bioreactor Effluent Channel level set point.

- 3) Provide individual permeate pump flow set points based on Total Permeate Production Rate and number of membrane trains in service.
- d. Air Scour:
 - 1) Determine the air scour flow required for membrane operations.
 - 2) The PLC shall control the air scour blowers based on the required air scour flow and pressure.
- e. Membrane Tank Level:
 - 1) Provide level transmitters for each membrane train.
 - 2) Receive level signals for each membrane train for monitoring and control.
3. Cleaning Systems:
 - a. General:
 - 1) PLC shall control sequence of backwashing and chemical cleanings.
 - 2) Record backwashes, air and water backwash duration, backwash flow, and perform calculations to determine permeate production rate.
 - 3) The MES Supplier shall supply the control functions for the cleaning cycles. When MES Supplier's cleaning sequence requires chemical pump to operate, a signal shall be sent to start the pump. Similarly, when MES Supplier's cleaning sequence requires chemical pump to stop, a signal shall be sent to stop the pump.
 - 4) All chemical cleaning systems shall be fully automated and shall not require manual operation of any equipment or valves.
 - b. Total air scour flow rate shall be monitored and controlled by the MES Supplier's PLC.
 - c. Backwash or Backpulse (if required): The backwash system shall perform the backwash function automatically at operator-entered time intervals, TMP, or per manual initiation by operator.
 - d. Maintenance Clean System:
 - 1) Designed for automatic operation controlled by the PLCs.
 - 2) Shall be automatically initiated based on time or an operator-entered number of backwashes/backpulses. System shall also allow operator to initiate a maintenance clean manually.
 - e. Recovery Clean System:
 - 1) Designed for automatic operation once a cleaning cycle has been initiated by the operator.
 - 2) Sequence shall permit an operator-initiated recovery clean abort in which the system will automatically stop the cleaning sequence and start the membrane trains.

- 3) MES Supplier's PLC shall send control signals to Plant Control System for control of drain valves, tank isolation gates, etc.
4. Alarms:
 - a. As a minimum, provide alarms for each train for high TMP, high permeate turbidity, low permeate flow, low agitation air flow, all high and low level alarms, permeate pump failure, and backpulse tank level high-high. Alarms shall also be sent to the Plant Control System.
 - b. Provide alarms for actuated valves supplied by MES Supplier for the failures to open or close the valves as intended by the MES control. Alarms shall also be sent to the Plant Control System.
 - c. Shutdown train, and alarm upon high TMP, turbidity above 0.5 NTU, and failure of any defined critical parameter or component.
 - d. Record and alarm power failures.
 - e. Provide listing of all alarm events and all other events that could cause a membrane train to shutdown or to be placed into standby or shutdown or any other nonproducing state.
5. Control Interface with Plant Control System:
 - a. Make available and receive in contiguous PLC data registers the following data to and from the Plant Control System:
 - 1) Output Data to the Plant Control System:
 - a) Status of each piece of equipment.
 - b) Hours of equipment/train operation.
 - c) Alarms.
 - d) Process variable values.
 - e) Control set points and control commands (START/STOP, OPEN/CLOSE) for equipment controlled by the Plant Control System.
 - 2) Input Data from the Plant Control System:
 - a) Process variable values monitored by the Plant Control System.
 - b) Operator entered values (e.g., set points), control actions (e.g., START/STOP), and operator selections (e.g., AUTO/MANUAL) same as provided at the Operator Interface Units.
 - c) Equipment status feedback for equipment controlled by the Plant Control System.
6. Miscellaneous SCADA Monitoring Points:
 - a. Include in the package control system the following points to be monitored and transferred to the SCADA system via the PLC:
 - 1) Utility Power On.
 - 2) Power Supplies OK.
 - 3) Ethernet Switch Fault.
 - 4) Panel Intrusion.

C. Performance Characteristics: None.

2.14 INSTRUMENTATION

A. Physical Characteristics:

1. General Requirements: Provide instrumentation described herein in accordance with Section 40 91 00, Instrumentation and Control Components. All transmitters with displays or tuning/programming controls shall be mounted for easy access at heights between 42 inches and 54 inches above floor. All instruments shall be mounted such that they are protected from damage such as can be caused by vibrations from pulsing flow. Where the MES Supplier's scope of supply includes certain sub-systems as stated elsewhere in the Contract Documents, the MES Supplier shall provide all instruments associated with the sub-system.
2. Provide instrumentation designated on P&IDs as part of the MES.
3. All instrumentation shall include HART-enabled electronics/transmitters, except where noted in Section 40 91 00, Instrumentation and Control Components.

B. Functional Characteristics:

1. Turbidity Elements and Transmitters:
 - a. Function: Continuously measures, indicate, and transmit signals proportional to turbidity of permeate.
 - b. Range: Provide turbidity elements and transmitters capable of measuring 0 NTU to 10 NTU.
2. Magnetic Flow Meters:
 - a. Function: Continuously measures, indicate, and transmit signals proportional to flow of membrane permeate and membrane backpulse for each train.
3. Air Flow Switches:
 - a. Function: Continuously monitor, indicate, and transmit flow or no-flow of air scour system to each train.
4. Pressure Differential Transmitter:
 - a. Function: Continuously measures, indicate, and transmit signals proportional to differential pressure of membranes for each train.
5. Pressure Transmitter:
 - a. Function: Continuously measures, indicate, and transmit signals proportional to pressure of membranes for each train.
6. Temperature Transmitter:
 - a. Function: Continuously measures, indicate, and transmit signals proportional to temperature of permeate discharge for the combined permeate.
7. Float Level Switches:

- a. Function: Provide in each membrane train for LOW level alarms and shutdown.
- 8. Level Transmitters:
 - a. Function: Provide noncontact level measurement in each membrane train. Technology used for level measurement shall be submitted by the MES Supplier, but shall include relay outputs for HIGH and LOW levels.
 - b. Function: Provide noncontact level measurement for the backpulse tank. Technology used for level measurement shall be ultrasonic, and shall include relay outputs for HIGH-HIGH, HIGH, LOW, and LOW-LOW levels.
- C. Performance Characteristics: In accordance with Section 40 91 00, Instrumentation and Control Components.

PART 3 EXECUTION

3.01 FACTORY INSPECTION AND TESTING

- A. Refer to Section 40 99 90, Package Control Systems, for additional factory testing requirements.
- B. Factory Inspections: Inspect all equipment and control panels for required construction, electrical connection, and intended function.
- C. The MES Supplier shall coordinate and conduct a Factory Test of the Membrane control system during which:
 - 1. The PLC control logic and HMI operability shall be demonstrated by systematically forcing I/O to verify all controls functions and HMI screen representations defined in the system control narrative.
 - 2. The Membrane control panel shall be inspected for completeness, and workmanship.
 - 3. The MES Supplier shall provide a minimum of 2 weeks' notice to the Contracting Officer prior to the Factory Test. The Contracting Officer may, at their option and the expense of others, choose to attend and witness the Factory Test.
 - 4. Whether or not the Contracting Officer attend the Factory Test, the MES Supplier shall provide written documentation and certification of the completed Factory Test.

3.02 INSTALLATION

- A. MES Supplier shall furnish written installation instructions and recommendations to Contractor.

- B. MES Supplier is responsible for furnishing all the components for a complete and operable system, and provide guidance for proper installation and integration of all MES components.
- C. Contractor shall install the MES in accordance with MES Supplier's instructions and recommendations.
- D. MES Supplier shall provide prompt assistance to Contractor during installation as requested.

3.03 TESTING AND COMMISSIONING

- A. Procedures: Per Section 01 91 14, Equipment Testing and Facility Startup.
- B. Following the MES Supplier's calibration of instruments, the MES Supplier shall coordinate and assist Contractor with Component Testing, Functional Testing, Software Operational Testing, Performance Testing, and Demonstration Testing on the installed MES. It will be the responsibility of the MES Supplier and Contractor to communicate to arrange the times for testing and startup activities, however, the Contractor must confirm that these times are acceptable to the Government.
- C. Component Testing, Functional Testing, Software Operational Testing:
 - 1. Refer to Section 01 91 14, Equipment Testing and Facility Startup, for additional testing requirements.
 - 2. Once written certification of proper installation has been issued after completion of Component Testing, MES Supplier shall coordinate with Contractor to perform Functional Testing and Software Operational Testing of the MES.
 - 3. For the Functional Testing and Software Operational Testing, the MES Supplier and the Contractor shall verify operation of all system components, all control system functions, and communication links.
 - 4. To perform the Functional Testing and Software Operational Testing, the MES Supplier shall operate all valves, controls, and other devices to ensure they are functional and ready for Performance Testing.
 - 5. Purpose of the Software Operational Testing shall be to demonstrate the effectiveness of the following system components and features:
 - a. Automatic START/STOP and flow control of membrane trains using Plant Control System.
 - b. Manual flow control using membrane train HMI and PLC.
 - c. Automatic backwashing, backpulse, or relaxation at various time intervals.
 - d. Automatic shutoff and alarm for various failure modes for each membrane train and for entire MES.
 - e. START and STOP of air system.

- f. Determination of clean water turbidity and permeability of each membrane train and temperature correction of the clean water permeability for each train.
 - g. Monitoring and recovery of operating data.
 - h. Monitoring and control from remote workstation.
 - i. Automatic switchover from normal power to emergency power, and emergency power to normal power.
 - j. All control functions, both at local system and remote workstation.
 - k. Operation of systems for maintenance and recovery cleans.
 - l. Operation of all monitoring instruments.
 - m. Bubble point testing of the small membrane subunits.
- 6. For the Functional Testing, the MES Supplier shall inspect the installed MES for correct operation, proper connection, and satisfactory function of all components. The MES Supplier shall approve the installation and provide to the Contracting Officer and Contractor written certification that the system components have been installed properly and are ready for operation.
 - 7. The proposed Software Operational Testing procedure shall be developed by the MES Supplier and shall be submitted to the Contracting Officer and reviewed by the Contractor and the Contracting Officer before scheduling and performing Software Operational Testing. In the case of a nonconforming system as determined by the Contracting Officer, advancement to Performance Testing shall not commence until the MES Supplier has made, at no additional cost to the Government, such adjustments and modifications as are necessary to correct the system, and has demonstrated this by repeating the Software Operational Testing until satisfactory.

D. Training:

- 1. Provide training in accordance with Section 01 91 14, Equipment Testing and Facility Startup, and as described herein.
- 2. MES Supplier shall provide training to Government's personnel as required for complete understanding of process, mechanical, electrical, and control system relationships.
- 3. Training shall be completed prior to commencement of Performance Testing.

E. Performance Testing:

- 1. Refer to Section 01 91 14, Equipment Testing and Facility Startup, for additional Performance Testing requirements.
- 2. Following completion of the Operational Readiness Testing and Training, and following the submittal of all final Shop Drawings, O&M Manuals, and PLC programs, the MES Supplier, Contractor, and the

Government shall conduct the Performance Test. Since the MES is part of the secondary treatment process, wastewater and mixed liquor shall be used for the entire duration of Performance Testing and the Performance Testing shall be conducted after successful startup of the secondary treatment facility as well as the preceding unit processes such as Fine Screens. During the Performance Test, the MES Supplier shall take the lead and be responsible to test the MES. The Contractor shall be responsible for testing all other equipment associated with the secondary process as part of the overall plant testing. The Government shall be responsible for controlling SRT and establishing mixed liquor solids concentrations as specified.

3. A Performance Testing procedure shall be developed by the MES Supplier and shall be submitted to the Government for review and approval by the Government and the Contracting Officer before scheduling and performing Performance Test; upon successful completion of the Software Operational test.
4. MES Supplier shall submit a Performance Test Report within 14 days of completion of the test period.
5. To perform the test, the MES Supplier shall provide full-time assistance to the Government over a 60-day test period, and collect and summarize data to demonstrate that the system meets the Performance test requirements for the parameters listed below. In all cases, compliance with the requirements of this Specification shall be determined for each calendar day, and to successfully pass the test, the MES must comply with requirements for each of the 60 days within the Performance Test period. During the 60 days, simulate annual average production for 15 days, then maximum month production for 29 days, then maximum day production for 18 hours, then peak production for 6 hours, then annual average production for 15 days. During the maximum month period, increase production rate by 50 percent to simulate recovery cleaning of another train. The duration of simulated recovery cleaning shall match the duration of proposed recovery cleaning.
 - a. Production Capacity: MES meets production capacity requirements as specified in Performance Requirements of this section.
 - b. Pressure Limitations: MES operates within the TMP requirements as specified in Performance Requirements of this section.
 - c. Membrane Permeate Quality: Membrane permeate meets requirements as specified in Performance Requirements of this section.
 - d. Maintenance Clean: Perform maintenance clean operation at the frequency equal to or less than specified in Performance Requirements of this section.
 - e. Recovery Clean: Perform recovery clean operation at the end of the 60-day test period on one membrane train. Using the TMP and temperature corrected permeability data from the 60-day

- operation, the recovery clean interval, when averaged over 1 year, shall not exceed more than four times a year.
- f. Air Scour Usage: Monitor average Air Scour rate for MES for duration of test period. Provide a test method prior to start of testing that is acceptable to the Government. Verify compliance with specified air scour requirements.
 - g. Chemical Use: Monitor chemical use for MES cleaning. Verify compliance with specified chemical use requirements.
 - h. Control System: Verify that the PLC, Process Control, HMI and network communications systems operate as intended. Verify that automatic transfer to redundant or backup systems is functional and that operator intervention to restart or to re-establish normal operation is required only during weekday periods between 8:00 a.m. and 4:00 p.m. Any other manual intervention to restart or to re-establish normal operation of the control system is considered a system failure.
- 6. Successful completion of the Performance Test will be defined as 60 continuous days of operation without a major failure in system and demonstration that the MES meets all performance requirements established herein.
 - 7. A major failure in the MES is one that decreases system capacity below 100 percent of design capacity for more than 24 hours, or, for control systems, a major failure is any event that requires operator intervention to restart or to re-establish normal system operation as described above.
 - 8. If the MES fails to successfully complete Performance Test, MES Supplier shall have the option of repeating the test over a second 60-day period. If the MES fails to successfully complete the Performance Test during second test period, MES Supplier shall prepare a written plan for modifying the system to meet all test requirements.
 - a. MES Supplier shall submit the written plan within 14 days after the second unsuccessful test period ends.
 - b. If the proposed modifications are deemed acceptable by the Government and the Contracting Officer, the MES Supplier shall modify the system within 30 days of receiving the Contracting Officer's written approval. All modifications to the system shall be completed at no additional cost to the Government or Contractor.
 - c. If any additional equipment, air scour, or cleaning chemicals is required, Contracting Officer shall calculate associated lifecycle costs for the new components incurred over a 10-year period. These associated costs shall be compensated in full by the MES Supplier in the form of a lump sum payment based on a 10-year net present worth calculation with a 5 percent discount rate.
 - d. After modifications are completed, the MES Supplier shall then repeat the Performance Acceptance Test.

- e. If, in the opinion of the Government or the Contracting Officer, the MES Supplier cannot modify or supplement its MES to meet performance requirements specified herein, the MES Supplier shall remove their system and install an alternate system as required to meet performance requirements at the sole cost of the MES Supplier. This requirement shall be secured by the Performance Bond.
9. During the Performance Test, Contractor and Government shall have the option of collecting samples for independent analyses to confirm measurements and analyses conducted by MES Supplier.
10. Government and Contracting Officer shall have the option of witnessing all testing performed by the MES Supplier.

F. Demonstration Testing:

1. Compliance with the requirements for production capacity, chemical cleaning interval, and membrane permeate quality shall be determined during the Demonstration Testing period.
2. The Demonstration Testing shall begin and end at the Government's discretion, within the limits defined herein:
 - a. Start of Commission: No later than 2 months after completion of Performance Acceptance Testing.
 - b. Duration: 180 days.
3. It is the Government's intent to time the Demonstration Testing to coincide with peak flow conditions, or to simulate those conditions using a substantial portion of the plant to the extent possible with the flow available at startup.
4. The Government shall operate the plant during the Demonstration Testing, however, MES Supplier and Contractor shall be allowed to provide onsite assistance.
5. MES Supplier is responsible for monitoring operating conditions and performance during the Demonstration Testing.
6. MES Supplier shall summarize data at the end of the Demonstration Testing and prepare a written report of the results to the Government and the Contracting Officer.
7. The Demonstration Testing Report shall include a narrative description, tables and graphs of production capacity, TMP versus time, air scour energy use, maintenance clean and recovery clean frequency, and other parameters to document the performance of the MES.
8. MES Supplier shall submit the Demonstration Testing Report within 30 days following the end of the Demonstration Testing.
9. The Government and Contracting Officer may conduct their own monitoring and record keeping during the Commissioning Period.

10. The following parameters shall be evaluated to determine compliance of the MES with Performance Requirements as stated herein:
 - a. Membrane Permeate Quality: If the MES fails to comply with requirements for membrane permeate quality, MES Supplier shall immediately provide to the Government and the Contracting Officer a written plan of modifications to the system (such as repairing damaged fibers, replacing seals, complete replacement of system) to achieve compliance with the requirements. Upon implementation of modifications plan, the commissioning tests shall re-commence in their entirety.
 - b. Production: If flow capacity does not meet specified requirements, and/or if TMP exceed requirements, MES Supplier shall immediately provide to the Government and the Contracting Officer a written plan of modifications to the system (such as repairing damaged fibers, replacing seals, complete replacement of system) to achieve compliance with the requirements. Upon approval by the Government and implementation of modifications plan, the commissioning tests shall re-commence in their entirety.
 - c. Cleaning Chemicals: If the interval for maintenance or recovery cleans during the Demonstration Testing is shorter than the specified frequency or if cleaning chemical consumption exceeds specified amounts to meet the production capacity as described under Performance Requirements, MES Supplier shall immediately provide to the Government and the Contracting Officer a written plan of modifications to the system (such as repairing damaged fibers, replacing seals, complete replacement of system) to achieve compliance with the requirements. Upon implementation of modifications plan, the commissioning tests shall re-commence in their entirety.
 - d. Air Scour: If air scour exceeds specified amounts during the Demonstration Testing, MES Supplier shall immediately provide to the Government and the Contracting Officer a written plan of modifications to the system (such as repairing damaged fibers, replacing seals, complete replacement of system) to achieve compliance with the requirements. Upon implementation of modifications plan, the commissioning tests shall re-commence in their entirety.

G. Telephone Support:

1. MES Supplier shall provide continuous (24 hour, 7 days per week, including weekends and holidays) telephone support by means of a toll-free phone number for a minimum period of 10 years following commissioning.
2. MES Supplier shall provide a list of names of three or more individuals qualified to support operation, and provide pager numbers for these

individuals, if available. At least one of the listed individuals shall be available at all times (24 hour, 7 days per week, including weekends and holidays) in the event of an emergency.

3.04 MEMBRANE EQUIPMENT SYSTEM SUPPLIER'S SERVICES

- A. Provide onsite services in accordance with Section 01 43 33, Manufacturers' Field Services, as described herein.
- B. In addition to the time necessary to complete the requirements established elsewhere within these Contract Documents, the MES Supplier shall provide the following onsite services at times designated by the Government and Contractor, for the minimum person-days listed below, travel time excluded. Time spent remedying equipment deficiencies/problems shall not count toward the listed person-days and trips.
 - 1. 10 person-days (three trips) for attendance at design workshops held at Contractor's or Government's office as specified in Section 01 43 33, Manufacturers' Field Services.
 - 2. 4 person-days (two trips) during unloading of MES, including attendance at a 1-day predelivery site meeting with the Contractor.
 - 3. 15 person-days (three trips) for providing installation assistance to the Contractor for the MES.
 - 4. 8 person-days (three trips) for training of Government's operators, including attendance at a 1-day prestartup meeting with the Contractor and the Government and a 2-day review of operations at the end of the first year of operation.
 - 5. Provide full-time assistance during Operational Readiness Testing and Performance Acceptance Testing Periods.
 - 6. 40 person-days (eight trips) for assistance during and after Commissioning Period.

END OF SECTION

