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USACE / NAVFAC / AFCEC **UFGS-46 30 13 (August 2025)**

Preparing Activity: USACE

Superseding
UFGS-46 30 13 (February 2011)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2025

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DIVISION 46 - WATER AND WASTEWATER EQUIPMENT

SECTION 46 30 13

ADVANCED OXIDATION PROCESSES (AOP)

08/25

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SECTION 46 30 13

ADVANCED OXIDATION PROCESSES (AOP)
08/25

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NOTE: This guide specification covers the requirements for liquid phase advanced oxidation processes including ultraviolet light (UV) peroxide, UV hypochlorite, UV ozone, UV titanium dioxide (UV-TiO2), and ozone-peroxide.

AOP is the treatment step to provide a pathogen and chemical barrier applied for drinking water treatment, groundwater treatment, indirect and direct potable reuse, and industrial wastewater treatment. AOP is used to remove trace organic compounds including NDMA (via photolysis) and 1,4-dioxane (via AOP). Additionally, AOP serves as a key pathogen barrier for regulatory compliance.

Each of these AOP systems requires different manufactured units, which impacts the subsections that need to be included under Part 2 PRODUCTS, and, therefore the applicable paragraph REFERENCES and paragraph SUBMITTALS. The following are a list of manufactured units required by type of AOP system.

UV Peroxide:
UV System
Hydrogen Peroxide Storage and Feed System

UV Hypochlorite:
UV System
Sodium Hypochlorite Storage and Feed System

UV Ozone:
UV System
Ozone Generation and Destruction System (and subsection for air or oxygen feed)
Note that reactor vessel is with UV system and a separate reactor vessel for ozone is not required

UV-TiO2:
UV System

Titanium Dioxide (TiO_2) Storage and Feed System

Ozone-Peroxide:
Ozone Generation and Destruction System (and subsection for air or oxygen feed)
Reactor Vessel
Hydrogen Peroxide Storage and Feed System

Adhere to UFC 1-300-02 **Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.**

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR)**.**
****

PART 1 GENERAL

1.1 REFERENCES

****
NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B1.1	(2024) Unified Inch Screw Threads (UN, UNR, and UNJ Thread Form)

ASME B1.20.1	(2013; R 2018) Pipe Threads, General Purpose (Inch)
ASME B1.20.2M	(2006; R 2011) Pipe Threads, 60 Deg. General Purpose (Metric)
ASME B16.1	(2020) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250
ASME B16.5	(2020) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.9	(2024) Factory-Made Wrought Buttwelding Fittings
ASME B16.11	(2021) Forged Fittings, Socket-Welding and Threaded
ASME B16.18	(2021) Cast Copper Alloy Solder Joint Pressure Fittings
ASME B16.20	(2023) Metallic Gaskets for Pipe Flanges
ASME B16.21	(2021) Nonmetallic Flat Gaskets for Pipe Flanges
ASME B16.22	(2021) Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B16.34	(2021) Valves - Flanged, Threaded and Welding End
ASME B31.1	(2024) Power Piping
ASME B36.19M	(2022; Errata 2023) Welded and Seamless Wrought Stainless Steel Pipe
ASME B40.100	(2022) Pressure Gauges and Gauge Attachments
ASME BPVC SEC IX	(2017; Errata 2018) BPVC Section IX-Welding, Brazing and Fusing Qualifications
ASME BPVC SEC VIII D1	(2023) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA B304	(2021) Liquid Oxygen for Ozone Generation for Water, Wastewater, and Reclaimed Water Systems
AWWA C111/A21.11	(2023) Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
AWWA C500	(2019) Metal-Seated Gate Valves for Water Supply Service

AWWA C504	(2023) Standard for Rubber-Seated Butterfly Valves
AWWA C508	(2017) Swing-Check Valves for Waterworks Service, 2 In. Through 48-In. (50-mm Through 1,200-mm) NPS
AWWA C509	(2023) Resilient-Seated Gate Valves for Water Supply Service

AMERICAN WELDING SOCIETY (AWS)

AWS B2.1/B2.1M	(2021) Specification for Welding Procedure and Performance Qualification
AWS D1.1/D1.1M	(2025) Structural Welding Code - Steel

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M	(2019) Standard Specification for Carbon Structural Steel
ASTM A53/A53M	(2024) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A126	(2004; R 2023) Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
ASTM A182/A182M	(2024) Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A193/A193M	(2025) Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service and Other Special Purpose Applications
ASTM A194/A194M	(2024) Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM A216/A216M	(2021) Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
ASTM A269/A269M	(2024) Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A276/A276M	(2025) Standard Specification for Stainless Steel Bars and Shapes
ASTM A312/A312M	(2022a) Standard Specification for Seamless, Welded, and Heavily Cold Worked

	Austenitic Stainless Steel Pipes
ASTM A351/A351M	(2024; E 2025) Standard Specification for Castings, Austenitic, for Pressure-Containing Parts
ASTM A403/A403M	(2025) Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
ASTM A436	(2024) Standard Specification for Austenitic Gray Iron Castings
ASTM A479/A479M	(2024) Standard Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
ASTM A536	(2024) Standard Specification for Ductile Iron Castings
ASTM A632	(2004; R 2014) Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service
ASTM A774/A774M	(2025) Standard Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures
ASTM A778/A778M	(2024) Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products
ASTM A789/A789M	(2024) Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service
ASTM A813/A813M	(2024) Standard Specification for Single- or Double-Welded Austenitic Stainless Steel Pipe
ASTM A814/A814M	(2015; R 2019) Standard Specification for Cold-Worked Welded Austenitic Stainless Steel Pipe
ASTM B32	(2020) Standard Specification for Solder Metal
ASTM B88	(2022) Standard Specification for Seamless Copper Water Tube
ASTM B88M	(2020) Standard Specification for Seamless Copper Water Tube (Metric)
ASTM B209/B209M	(2021a) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM D1710	(2008) Extruded and Compression Molded Polytetrafluoroethylene (PTFE) Rod and

Heavy-Walled Tubing

ASTM D1785 (2021) Standard Specification for Poly(Vinyl Chloride) (PVC), Plastic Pipe, Schedules 40, 80, and 120

ASTM D2241 (2020) Standard Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)

ASTM D2564 (2020) Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems

ASTM D2584 (2018) Standard Test Method for Ignition Loss of Cured Reinforced Resins

ASTM D3222 (2018a) Standard Specification for Unmodified Poly(Vinylidene Fluoride) (PVDF) Molding Extrusion and Coating Materials

ASTM D3308 (2012; R 2022) Standard Specification for PTFE Resin Skived Tape

ASTM F593 (2024) Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs

COMPRESSED AIR AND GAS INSTITUTE (CAGI)

CAGI B19.1 (2010) Safety Standard for Compressor Systems

COMPRESSED GAS ASSOCIATION (CGA)

CGA G-4.1 (2009) Cleaning Equipment for Oxygen Service; 6th Edition

CGA G-4.4 (2020) Oxygen Pipeline Systems; 4th Edition

CGA HB (1999) Handbook of Compressed Gases; 4th Edition

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 519 (2022) Standard for Harmonic Control in Electrical Power Systems

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 228-1 (2000) Pipe Threads Where Pressure-Tight Joints Are Not Made on The Threads - Part 1: Dimensions, Tolerances and Designation

INTERNATIONAL SOCIETY OF AUTOMATION (ISA)

ANSI/ISA 5.1 (2024) Instrumentation Symbols and Identification

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-43	(2019) Wrought Stainless Steel Butt-Welding Fittings
MSS SP-58	(2018) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C82.4	(2017; R 2022) Lamp Ballasts - Ballasts for High- Intensity-Discharge and Low-Pressure Sodium Lamps
NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ICS 1	(2022) Standard for Industrial Control and Systems: General Requirements
NEMA ICS 6	(1993; R 2016) Industrial Control and Systems: Enclosures

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 55	(2023; TIA 22-1; TIA 22-2; TIA 23-3; TIA 23-4) Compressed Gases and Cryogenic Fluids Codes
NFPA 70	(2023; ERTA 1 2024; TIA 24-1; TIA 25-2) National Electrical Code

NSF INTERNATIONAL (NSF)

NSF/ANSI/CAN 61	(2024) Drinking Water System Components - Health Effects

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-301-01	(2023; with Change 3, 2025) Structural Engineering

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA 815-R-06-007	(2018) Sustainable Environmental Engineering

1.2 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that

require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.
****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

UV AOP System; G, [_____]

Air Preparation System; G, [_____]

Hydrogen Peroxide Storage And Feed System; G, [_____]

Oxygen Generation System; G, [_____]

LOX Storage and Supply System; G, [_____]

Ozone Generation System; G, [_____]

Reactor Vessel; G, [_____]

[Sodium] Hypochlorite Storage And Feed System; G, [_____]

Metering Pump; G, [_____]

Local Controls and Panels; G, [_____]

Liquid Process Tank; G, [_____]

Maintenance; G, [_____]

Drawings showing shop and erection details and chemical application locations; including cuts, codes, connections, holes, bolts, welds, anchorage, installation details, wiring diagrams, schematic diagrams, component identification tables and directory, and clearances for maintenance and operations.

SD-03 Product Data

UV AOP System; G, [_____]

Hydrogen Peroxide Storage And Feed System; G, [_____]

Calculations; G, [_____]

Acceptance Test Plan; G, [_____]

Manufactured Units

Performance Requirements; G, [_____]

Qualifications; G, [_____]

[Sodium] Hypochlorite Storage And Feed System; G

Oxygen Generation System; G, [_____]

Reactor Vessel; G, [_____]

SD-06 Test Reports

Performance Requirements; G, [_____]

SD-07 Certificates

UV AOP System

Hydrogen Peroxide Storage And Feed System; G, [_____]

[Sodium] Hypochlorite Storage And Feed System; G, [_____]

Field Training

Oxygen Generation System; G, [_____]

Reactor Vessel; G, [_____]

SD-10 Operation and Maintenance Data

UV AOP System; G, [_____]

Hydrogen Peroxide Storage And Feed System; G, [_____]

[Sodium] Hypochlorite Storage And Feed System; G, [_____]

Maintenance; G, [_____]

Oxygen Generation System; G, [_____]

Reactor Vessel; G, [_____]

1.3 QUALIFICATIONS

****
NOTE: Designer should edit the subsequent paragraphs and remove requirements not applicable to the project.
****

1.3.1 Contractor

Provide documentation of a minimum of [3] [_____] years of experience in the construction of water, wastewater, industrial wastewater, or hazardous and toxic wastewater treatment facilities. The Contractor is responsible for installation and start-up of the AOP equipment supplied, as well as operator training.

1.3.2 Equipment Manufacturer

Submit a statement by the equipment manufacturer listing any exception to or deviations from the contract drawings and specifications. Written evidence that equipment and accessories are a product of a qualified and experienced manufacturer. Statement indicating the system is capable of treating the wastes to the levels identified.

1.3.3 Ultraviolet (UV) Oxidation System Supplier

Provide equipment to duplicate equipment that has been in satisfactory service for a minimum of [2] [_____] years prior to bid opening. The UV oxidation system supplier is responsible for furnishing a complete prepackaged system. The supplier need not manufacture the entire system, but coordinate the selection, assembly, installation, and testing of the entire system as specified.

1.3.4 Manufacturer's Representative

Provide services, as specified, of a qualified manufacturer's field representative experienced in the installation, adjustment, and operation of the equipment furnished and who has complete knowledge of the proper operation and maintenance of the system. Include a statement indicating the operators designated to train the on site operators have been trained to operate the installed equipment.

1.3.5 Welding

Perform welding following qualified procedures, using performance qualified welders and welding operators. Furnish a copy of qualified procedures and a list of names and identification symbols of qualified welders and welding operators to the Contracting Officer prior to beginning any work on the AOP equipment.

1.4 REGULATORY REQUIREMENTS

Conform the AOP system to all federal, state, regional, and local regulations concerning chemical storage, air, noise and water pollution control requirements.

1.5 PRE-SUBMITTAL CONFERENCE

Assemble the primary process designer, AOP equipment and major component suppliers, electrical and mechanical subcontractors, and major component manufacturer's representatives at [the construction site] [_____] prior to preparation of the Contractor's AOP submittal for government approval. This meeting is intended to ensure that facility construction is properly scheduled; power, control, plumbing, space interfaces are verified; and responsibilities coordinated among subcontractors and suppliers and reflected on the Contractor's AOP submittals.

1.6 DELIVERY, STORAGE, AND HANDLING

****

NOTE: Designer should coordinate with the Contracting Officer and user to determine appropriate locations for equipment storage. Identify unusual requirements either here or on the drawings.

****

Deliver equipment free of structural or other damage and place in storage, in accordance with the manufacturer's requirements, protected from structural damage, the weather, excessive humidity and excessive temperature variation; and dirt, dust, or other contaminants that could otherwise damage its components.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

****

NOTE: This paragraph should be edited to identify the appropriate contaminants of concern as well as those parameters which potentially inhibit the process.

Effluent limitations are generally dictated by regulatory requirements. List the performance requirements in this specification.

If this specification is used as part of a Request for Proposals, the designer should identify maximum values for power and oxidant usage based on bench or pilot studies and include this information in paragraph PERFORMANCE REQUIREMENTS.

The specifier updates the design requirements table below per manufacturer's recommendation. The default values shown in table are based on Trojan's recommendations.

****

Provide the AOP including all items necessary as a complete system for removal of those chemicals identified below to the levels indicated. Equipment includes, but is not limited to, AOP contact vessels, lamps when required, piping to units upstream and downstream of the contact vessels, oxidant feed system, gas emission treatment, controls, accessories and equipment to provide complete and functional system within the limits identified. Analytical and sampling protocols areas specified in [_____].

2.1.1 Design Requirements

Minimum equipment life	[20] [_____] years
Max. equipment dimensions	[As indicated] [_____] [2660 mm x 1416 mm x 1619 mm] [8.7 feet x 4.6 feet x 5.3 feet]
Maximum AOP reactor operating pressure	[_____] [413.7 kPa] [60 psi]
Reactor inlet pipe diam.	[_____] [900 mm] [2.9 feet]
Reactor outlet pipe diam.	[_____] [900 mm] [2.9 feet]
Max. AOP influent flow rate	[_____] [120 L/s gpm]
Minimum reactor vessel detention time	1 minute

2.1.2 Performance Requirements

Submit performance tests results indicating temperature rise through the reactor, oxidant dosage, detention time, catalyst dosage, ultraviolet light dosage, ambient gas monitoring results, and treatment system off gas monitoring and destruction results, equipment and analytical testing methods used, and removal of constituents identified below stated in mass/unit volume treated relative to the influent concentration.

Report in booklet form, upon completion of the installed system. Test report will include field tests performed to adjust each component and field tests conducted to prove compliance with the specified performance criteria. Indicate recommended position of the controls in test report.

a. Influent characteristics:

Inorganic Constituent Concentration	
Iron (Fe2+)	[_____] mg/L
HCO3- (as CaCO3)	[_____] mg/L
[_____]	[_____] mg/L

General	
pH	[_____] units
Color	[_____] unit
TDS	[_____] mg/l

TSS	[_____] mg/l
Organic Constituent Concentration	
Total Organic Carbon (TOC)	[_____] mg/L
NDMA	[_____] ug/L
1,4-Dioxane	[_____] ug/L

b. Effluent requirements:

Organic Constituent Concentration	
Total Organic Carbon (TOC)	[_____] mg/L
NDMA	[_____] ug/L
1,4-Dioxane	[_____] ug/L
General	
pH	[_____] units
Maximum effluent temperature	[_____] degrees C F

c. Efficiency factors:

[Ozone usage]	[_____] mg/L
[Hydrogen peroxide usage]	[_____] mg/L
Power consumption	[_____] kW/L
[Sodium hypochlorite usage]	[_____] mg/L

[2.1.3 Treatability Testing

****

NOTE: This paragraph should be deleted if previous treatability studies have not been conducted. The system parameters used during the treatability study may not duplicate the system proposed by the Contractor.

****

The previously conducted treatability study information contained in Appendix [_____] is provided for the Contractor's information. The study results indicate [ultraviolet oxidation] [ozone-peroxide] [_____] is capable of meeting the criteria in paragraph PERFORMANCE REQUIREMENTS. Evaluate the applicability and adequacy of the treatability studies and results provided. If deemed necessary by the Contractor, additional studies may be performed at the Contractor's expense to confirm the previously conducted treatability study and results. Based on the Contractor's own interpretation of the previous studies and results, and additional studies and results the Contractor elects to perform, provide a full scale treatment plant which meets the requirements identified.

]2.2 STANDARD PRODUCTS

Provide materials and equipment which are the standard products of a manufacturer regularly engaged in the manufacture of such products and which essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening. Support equipment by a service organization that is, in the opinion of the Contracting Officer, reasonably convenient to the site.

2.3 NAMEPLATES

Provide each major item of equipment with the manufacturer's name, address, type or style, model or serial number, and catalog number on a plate secured to the item of equipment. Provide nameplates for, but not limited to, each contact vessel, pumps, motors, oxidant equipment and accessories, and electrical components such as transformers.

2.4 MATERIALS

2.4.1 Plates, Shapes and Bars

Conform steel to ASTM A36/A36M; conform stainless steel to ASTM A276/A276M, Grade TP316.

2.4.2 Pipe and Fittings

****

NOTE: Designer should coordinate with the oxidizer equipment suppliers to coordinate piping and gasket material requirements.

NOTE: Designer can refer to Section 40 05 13 PIPELINES, LIQUID PROCESS PIPING for pipe and fittings if stainless steel, copper, PVC, and PVDF pipe and fittings are used. If PTFE tubing and fittings are used, paragraph POLYTETRAFLUOROETHYLENE (PTFE) PIPE AND TUBING would either need to remain in this specification or be added to Section 40 05 13 PIPELINES, LIQUID PROCESS PIPING.

****

Provide silicone, or teflon gasket materials for pipe and fittings unless otherwise shown or specified.

2.4.2.1 Stainless Steel Pipe

a. Conform pipe 100 mm 4 inch and larger to ASTM A312/A312M, Schedule 40, Grade TP316L with maximum carbon content of 0.04 percent. Conform flanged fittings to ASME B16.5, F316L Class 150 with 2 mm 1/16 inch minimum thickness silicone, teflon, expanded PTFE, PVDF, or viton gaskets. Design butt weld fittings to conform to ASTM A403/A403M and MSS SP-43, Grade TP316L, Schedule 10S with full penetration welds.

b. Pipe less than 100 mm 4 inch will be Grade TP316, and conform to

ASTM A312/A312M Schedule 80S for threaded joints, and Schedule 40S for welded joints. Conform flanged joints to ASTM A182/A182M, F316 or F316L, Class 150; dimensions and drilling to comply with ASME B16.5 with 2 mm 1/16 inch minimum thickness silicone, teflon, expanded PTFE, PVDF, or viton gaskets. Design butt weld fittings to conform to ASTM A774/A774M, ASTM A778/A778M, and ASME B16.9.

c. Liquid tubing 10 mm 3/8 inch and smaller will be seamless austenitic stainless steel and conform to ASTM A269/A269M, Grade TP316. Provide adequate wall thickness for the pressure required. Provide compression type fittings made from bar stock material conforming to ASTM A276/A276M, Grade TP316, with forgings conforming with ASTM A182/A182M, Grade TP316. Assemblies will consist of tube, fittings and components of one manufacturer.

2.4.2.2 Polyvinyl Chloride (PVC) Pipe

PVC pipe and fittings less than 100 mm 4 inch diameter will be in accordance with ASTM D1785 or ASTM D2241. PVC pipe and fittings 100 mm 4 inch in diameter and larger will be in accordance with ASTM D2241. Rate pipe and joints for a working pressure of [_____] kPa psi. Provide solvent cement joints to conform to the requirements of ASTM D2564. Provide flanged joint diameter and drilling to conform to ASME B16.5, Class 150.

2.4.2.3 Polytetrafluoroethylene (PTFE) Pipe and Tubing

Conform pipe and fittings to ASTM D1710, Type I, Grade 1, Class A, with PTFE compression type fittings. Rate pipe, tubing and associated fittings for a minimum working pressure of [_____] kPa psi.

2.4.2.4 Polyvinylidene Fluoride (PVDF) Pipe and Tubing

Manufacture PVDF pipe, tubing and fittings from materials conforming to ASTM D3222 for type II homopolymers. Comply with ASTM D1785 schedule 80 pipe for pipe tolerances for outside diameter and wall thickness. Rate tubing and associated fittings for a minimum working pressure of [_____] kPa psi.

2.4.2.5 Copper Pipe

Provide 100 mm 4 inch and smaller standard weight, seamless, cold drawn type pipe conforming to ASTM B88M ASTM B88 Type K, temper H. Provide cast or wrought copper alloy fittings, solder joint type, conforming with ASME B16.18 or ASME B16.22, as appropriate. Provide lead-free solder used and comply with ASTM B32, grade Sb5, 95-5 tin-antimony or Sn96, 96-4 tin-silver solder.

2.4.3 Pipe Hangers and Supports

Conform to MSS SP-58 for pipe hangers and supports.

2.4.4 Stainless Steel Gas Tubing and Fittings

Conform to ASTM A778/A778M for stainless steel tubing. Provide a minimum of 1.5 mm 0.062 inch wall thickness for tubing 250 mm 10 inches and smaller, a minimum wall thickness of 1.9 mm 0.078 inch for tubing 300 mm 12 inch in diameter, and a minimum wall thickness of 2.7 mm 0.109 inch for tubing 350 through 450 mm 14 through 18 inch in diameter. Conform to

ASTM A774/A774M, with the same material, grade, schedule or wall thickness for fittings as specified for tubing. Provide full penetration butt welded joints or Van Stone type joints using angle face rings with bracing flanges drilled in accordance with ASME B16.5.

2.4.5 Valves and Piping

****
NOTE: Specify the 304 or 316 SS valves and pipings by designer used for UV-AOP applications.
****

2.4.5.1 Liquid Oxygen (LOX)

Provide bronze or Grade TP316 stainless steel LOX valves intended for cryogenic extended service. Provide materials compatible with the piping installed.

2.4.5.2 Gate Valves

2.4.5.2.1 General Service Gate Valves

Provide general service gate valves conforming to the following:

a. Provide gate valves, 50 mm 2 inch and smaller, with [bronze] [_____] bodies and stems, [screwed] [union] [bolted] [yoke] bronze [_____] bonnets, single [solid] [split] wedge bronze discs, and [rising] [non-rising] stems. Provide valves rated for[1.2 MPa 175 psig] [[_____] MPa psig] service and conforming to ASME B16.34 Class [_____]. Provide [ASME B16.5 flanged] [ASME B16.1 flanged] [ASME B16.11 threaded] [_____] end connections. Equip valves with [handwheel] [pneumatically actuated] [electrically actuated] [_____] operators.

****
NOTE: The requirements of the below are based on general water service and AWWA ratings.
****

b. Provide gate valves, 65 mm 2.5 inch and larger, with [Ni-resistant] [3 percent nickel-iron] [cast-iron] [_____] bodies with [iron] [bronze] [Ni-resistant stainless steel] [_____] trim. Provide valves meeting the requirements of [AWWA C500] [AWWA C509] and have Class [125] [250] [_____] [flanged] [welding] [threaded, in accordance with ASME B1.20.2M, ASME B1.20.1,] [mechanical joint] [push-on] [_____] end connections. Provide a [clamp] [OS&Y Bolted] [NRS Bolted] type bonnet. Provide [wedge] [double] type discs of [iron] [bronze] [ductile iron] [bronze faced iron] [rubber coated ductile iron] [_____] construction, and have [nonrising] [rising] stems [with backseats]. Include a by-pass of the same materials as the gate valve for each gate valve, 400 mm 16 inch and larger. Provide bypass meeting the requirements of AWWA C500. Use valves rated for[1.4 MPa 200 psig] [[_____] MPa psig] service. Equip valves with [handwheel] [pneumatically actuated] [electrically actuated] [_____] operators.

2.4.5.3 Ball Valves

****
NOTE: If not available for top or bottom entry

bronze ball valves, require additional unions for an end entry valve or ability to spring pipe clear in order to service valve. Provide readily removable flanged and wafer style valves.
****

2.4.5.3.1 General Purpose Ball Valves

Provide general purpose ball valves conforming to the following:

a. Provide end entry type for 50 mm 2 inch and smaller vall valves with [bronze] [brass] [_____] bodies and [threaded, in accordance with ASME B1.20.2MASME B1.20.1,] [soldered] [_____], [full bore] [regular] ports. Provide valves with [polytetrafluoroethylene (PTFE)] [_____] seats and packing, [chrome plated] [brass] [stainless steel] [_____] balls and [hand lever] [tee-handle] [hand wheel] [pneumatically actuated] [electrically actuated] [_____] operators. Ensure valves are rated for[2.76 MPa 400 psig] [[_____] MPa psig] service at 66 degrees C 150 degrees F and conform to ASME B16.34 Class [_____]. [Install a union adjacent to the valves to provide access to the seat.]

b. Provide end entry type for 65 mm 2.5 inch and larger ball valves with [bronze] [cast iron] [_____] bodies and [ASME B16.11 socket-welding] [ASME B16.11 threaded] [ASME B16.5 flanged] [ASME B16.1 flanged] [ASME B16.18 solder joint] [_____] ends. Provide valves with [polytetrafluoroethylene (PTFE)] [_____] packing and seats, a [chrome plated] [brass] [stainless steel] [_____] ball, [regular] [full bore] ports, and [hand lever] [tee-handle] [hand wheel] [pneumatically actuated] [electrically actuated] [_____] operators. Ensure valves are rated for[2.76 MPa 400 psig] [[_____] MPa psig] service at 66 degrees C 150 degrees F and conform to ASME B16.34 Class [_____].

c. Provide ball valves, 50 to 300 mm 2 to 12 inch, conforming to ASME B16.34 Class [_____], and with a [cast iron] [ductile iron] [carbon steel] [bronze] [TP316 stainless steel] [_____] body, stainless steel ball and stem, polytetrafluoroethylene (PTFE) packing and gasket, and [flanged] [welding] [_____] ends, full port. Ensure valves are rated for[1.38 MPa 200 psig] [[_____] MPa psig] service, and have [hand lever] [pneumatically actuated] [electrically actuated] [_____] operators.

d. Passivate and vent valves used for hydrogen peroxide service in accordance with the hydrogen peroxide supplier recommendations.

2.4.5.3.2 Multiple Piece Body Ball Valves

Provide multiple piece body ball valves, 40 to 150 mm 1.5 to 6 inch, with [three] [_____] piece bodies constructed of [stainless steel ASTM A276/A276M Grade [TP316] [_____]] [cast steel ASTM A351/A351M Grade [CF8M] [_____]] [ASTM A216/A216M] [_____] stainless steel. Design a [TP316] [_____] stainless steel ball, and [ASME B16.11 threaded] [ASME B16.5 flanged] [_____] end connection valves. Ensure valves rated for[6.89 MPa 1000 psig] [_____] service and conform to ASME B16.34 Class [_____]. Provide valves with [reinforced polytetrafluoroethylene (PTFE)] [_____] seats and stem packing, that are [full] [standard] bore, and equipped with [handwheel] [hand lever] [tee-handle] [pneumatically actuated] [electrically actuated] [_____] operators.

2.4.5.4   Check Valves

****

NOTE: "Check valves" are generally service oriented. Specific types of check valves should be specified for the specific applications; for example, the ball check valve is capable of passing solids. Rated operating pressures vary based on body and seat materials, size and other parameters such as wafer class. Consult manufacturer's information to select the appropriate rating for the application. Piping plane and valve orientation may affect check valve performance. Certain types of check valves will only operate under specific conditions; for example, lift check valves can only operate in horizontal lines, and swing check valves can operate in either horizontal or vertical (flow up) positions.

****

2.4.5.4.1   Swing Check Valves

****

NOTE: The requirements below are based on general water service and AWWA ratings.

****

Provide swing check valves conforming to the following:

a. Provide swing check valves, 50 mm 2 inches and smaller, with a [cast iron] [ductile iron] [carbon steel] [bronze] [TP316 stainless steel] [_____] body, in accordance with [ASME B16.11 socket-welding] [ASME B16.11 threaded] [ASME B16.5 flanged] [ASME B16.1 flanged] [ASME B16.18 solder joint] [_____] ends. Provide valves with a swing type, replaceable [butadiene acrylonitrile] [polytetrafluoroethylene (PTFE)] [_____] disc. Ensure valves are rated for[1.4 MPa 200 psig] [[_____] MPa psig] service.

b. Provide swing check valves, 65 mm 2.5 inches through 300 mm 12 inch, with a [cast iron] [ductile iron] [carbon steel] [bronze] [TP316 stainless steel] [_____] body, in accordance with [ASME B16.11 socket-welding] [ASME B16.11 threaded] [ASME B16.5 flanged] [ASME B16.1 flanged] [_____] ends. Provide valves with a bronze-mounted swing type, [bronze] [ductile iron] [cast iron] [_____] disc, [solid bronze] [ductile iron] [_____] hinges, and stainless steel hinge shaft [with outside lever and [weight] [spring]]. Ensure valves are rated for[1.4 MPa 200 psig] [[_____] MPa psig] service.

c. Provide swing check valves, 50 mm 2 inch through 900 mm 36 inch, conforming to AWWA C508, and have [ASME B16.1 Class [_____] flanged], [welding], [mechanical joint] [grooved] [_____] end connections. Provide valves with a [cast iron] [ductile iron] [carbon steel] [bronze] [TP316 stainless steel] [_____] body, [bronze] [_____] -mounted disc, solid [bronze] [ductile iron] [_____] hinges, and a stainless steel hinge shaft. Provide valves 50 mm 2 inch through 300 mm 12 inch rated for[1.2 MPa 175 psig] [[_____] MPa psig] service and valves 350 through 900 mm 14 through 36 inch rated for[1.03 MPa 150 psig] [[_____] MPa psig] service at 60 degrees C 140 degrees F. Fit valves with an [adjustable outside lever and spring] [adjustable outside lever and weight]. An increasing-pattern body valve may be used where increased outlet piping size is shown.

2.4.5.4.2 Double Disc Swing Check Valve

Provide wafer style, spring loaded swing check valve for 50 mm 2 inch through 1300 mm 52 inch double disc swing check valves, with a [cast iron] [ductile iron] [carbon steel] [bronze] [TP316 stainless steel] [_____] body, a [aluminum-bronze] [ductile iron] [stainless steel] [bronze] [carbon steel] [_____] disc, resilient seats, stainless steel hinge pin, and a stainless steel stop pin spring. Ensure valves 50 mm 2 inch through 300 mm 12 inch are rated for[1.4 MPa 200 psig] [[_____] MPa psig] service at 60 degrees C 140 degrees F and valves 350 mm 14 inch through 1300 mm 52 inch are rated for[1.03 MPa 150 psig] [[_____] MPa psig] service at 60 degrees C 140 degrees F.

2.4.5.5 Butterfly Valves

****

NOTE: Refer to AWWA C504 and manufacturers' data for valve selection and torque calculation data. Only valves with high velocities, heavy grit loads, or severe throttling service should be specified with a seat in the body.

****

2.4.5.5.1 Standard Service Butterfly Valve

Provide butterfly valves, 50 mm 2 inch and larger, with [ASTM A126 cast iron] [ductile iron] [carbon steel] [stainless steel] [_____] bodies, [[wafer] [lugged] styled] [with [ASME B16.5 flanged] [ASME B16.1 flanged] [AWWA C111/A21.11 mechanical joint] [_____] end connections]. Provide valves conforming to [AWWA C504 Class [125] [150] [_____]] [ASME B16.34 Class [_____]]. Contour discs [ASTM A436 Type 1 Ni-resist cast iron with maximum lead content of 0.003 percent] [ASTM A536 Grade 65-45-12 ductile iron] [stainless steel] [polyvinylidene fluoride (PVDF) coated ductile iron] [bronze] [_____]. Provide [carbon steel] [stainless steel] [_____] valve shafts with self-lubricating, corrosion-resistant sleeve type bearings. Provide valve seats, constructed of [chloroprene] [_____], for[600 mm 24 inch] [_____] and smaller valves and attach to either the valve body or the disc. Provide valve seats for valves larger than[750 mm 30 inch] [[_____] mm inch] which are field replaceable in accordance with AWWA C504. Provide valves with [manual, locking hand lever] [hand wheel] [crank] [chain wheel] [pneumatically actuated] [electrically actuated] [_____] operators.

2.4.5.6 Stainless Steel Piping System

****

NOTE: The following paragraphs specify general liquid service use of stainless steel piping. To specify the material, review the application. For example, of the austenitic steels, TP316 or TP316L have better resistance to pitting corrosion than TP304 or TP304L where brines, sulphur-bearing waters or halogen salts, such as chlorides, are present. The option for crimped couplings and fittings requires a low pressure application - less than 1.03 MPa 150 psig, service where the stainless steel

piping materials (TP304, TP304L, TP316 and TP316L) are compatible to the fluid and thin wall (schedule 5S) pipe or tubing. A limited number of manufacturers are available so include other joint/fitting option(s).
****

2.4.5.6.1   Austenitic Piping

2.4.5.6.1.1   Stainless Steel Pipe

Provide stainless steel pipe intended for general corrosive service to meet the requirements of [ASTM A312/A312M, [seamless] [welded]] [ASTM A813/A813M for fit-up and alignment quality, Class [SW] [DW]] [ASTM A814/A814M for flanged and cold-bending quality, Class [SW] [DW]] [_____], Grade [TP304] [TP304L] [TP316] [TP316L] [_____], Schedule [10S] [40S] [80S] [5S] [in accordance with Pipe Schedule] [_____] with dimensions conforming to ASME B36.19M.

2.4.5.6.1.2   Stainless Steel Tubing

Provide stainless steel tubing meeting the requirements of [[ASTM A269/A269M] [ASTM A632], [seamless] [welded], Grade [TP304] [TP304L] [TP316] [TP316L] [_____]] [ASTM A789/A789M, [seamless] [welded], Grade [S32760] [_____]] with nominal size and wall thickness [in accordance with Pipe Schedule] [_____].

2.4.5.6.1.3   Stainless Steel Joints

Join stainless steel piping by [threaded couplings] [welded fittings] [flanges] [crimping couplings]. Join tubing using [crimping couplings] [compression] [_____] fittings. Provide dielectric fittings or isolation joints between all dissimilar metals.

2.4.5.6.1.4   Stainless Steel Threaded Fittings

Provide threaded fittings consisting of [austenitic stainless steel, [ASTM A182/A182M Grade [TP304] [TP304L] [TP316] [TP316L] [_____], conforming to [ASME B16.11] [_____], and threaded in accordance with ASME B1.20.2M ASME B1.20.1.]] Use [polytetrafluoroethylene (PTFE) pipe-thread tape conforming to ASTM D3308] [_____] for lubricant/sealant.

2.4.5.6.1.5   Stainless Steel Welding Fittings

Provide [butt-welding] [or] [socket-welding] welding fittings. Provide welding fittings consisting of forged austenitic stainless steel, [ASTM A403/A403M Grade [TP304] [TP304L] [TP316] [TP316L] [_____], [butt-welding fittings, Class [CR], conforming to ASME B16.9] [socket-welding fittings, Class [WP-S] [WP-W] [WP-WX] [WP-WU], conforming to ASME B16.11].] [_____].

2.4.5.6.1.6   Stainless Steel Flanged Fittings

Provide internal diameter bores of flanges and flanged fittings that are the same as that of the associated pipe. Ensure flanges are [welding neck] [slip-on] [socket welding] [lapped] [or] [threaded] type. Provide flanges and flanged fittings consisting of [forged austenitic stainless steel, ASTM A182/A182M Grade [TP304] [TP304L] [TP316] [TP316L] [_____]] [_____], Class [150] [300] [_____], drilled to ASME B16.5 with a[1.6 mm

0.0625 inch raised face] [flat face] [_____]. [Drill cast austenitic stainless steel backing flanges, ASTM A351/A351M Grade [_____], Van Stone type, to [ASME B16.5] [ASME B16.1] Class [150] [_____].] For tie-in to existing flanges, field check existing flanges for non-standard bolt hole configurations and design as required to assure new pipe and flange mate properly. Conforms to [alloy-steel ASTM A193/A193M Grade [B8] [B8C] [_____] hex head bolts and ASTM A194/A194M Grade [8] [8C] [_____] hex head nuts] [_____] for bolting. When mating flange on valves or equipment is cast iron, use [ASTM A193/A193M Grade [B8 Class 1] [_____] bolts and ASTM A194/A194M Grade [8] [_____] heavy hex head nuts] [_____]. Provide bolts with washers of the same material as the bolts. Provide gaskets meeting the requirements of ASME B16.5. [Provide nonmetallic gaskets conforming to ASME B16.21 and that are a maximum [3] [_____] mm [1/8] [_____] inch thick [chloroprene rubber, durometer hardness No.80] [_____], 10.34 MPa 1,500 psi minimum tensile strength, [125] [_____] percent minimum elongation, flat ring type for use with raised face flanges and full face type for use with flat face flanges.] [Provide metallic ring joint gaskets conforming to ASME B16.20 and constructed of [_____].]

2.4.5.6.1.7 Stainless Steel Crimping Fittings

Provide cold drawn, [TP304] [TP304L] [TP316] [TP316L] austenitic stainless steel crimping fittings. Provide [butadiene acrylonitrile] [ethylene propylene diene monomer (EPDM)] [fluoro-elastomeric] [_____] O-ring seals.

2.4.5.6.1.8 Compression Fittings for Tubing

Provide compression fittings consisting of [ASTM A479/A479M] [_____] stainless steel, Grade TP316, nuts, ferrules and bodies rated to a minimum [_____] kPa psig. Provide straight threads conforming to [ISO 228-1] [ASME B1.1].

2.4.5.6.1.9 Stainless Steel Cathodic Protection

Provide cathodic protection for buried ferrous piping.

2.4.6 Injectors

****

NOTE: Designer should coordinate pressure requirements with equipment manufacturers to determine if supplemental pumping is required to ensure adequate gas transfer. In certain situations, multiple injectors may be required if large flow variations are expected. Injectors are most commonly used on smaller applications such as multiple columns in series where ozone can be injected to the individual columns.

****

High efficiency venturi type injectors will be constructed of Grade TP316L stainless steel or PVDF at a rated pressure of [_____] kPa psi. Each unit will have a liquid flow capacity of [_____] L/s gpm, and be capable of applying 150 percent of the design gas flow of standard [_____] L/minute cubic feet/hour of a [_____] percent ozone in [air] [oxygen] mixture. Design injectors to operate with an available pressure head to the injector of [_____] kPa psi, and a back pressure of [_____] kPa psi.

2.4.7 Diffusers

****
NOTE: Designer should coordinate with diffuser manufacturers to determine the proper flow rate and coverage per diffuser. Rod type diffusers are generally used on larger rectangular tanks versus the dome or disc type which can be used in either circular reactors, or on rectangular units.

Coordinate access requirements with paragraph REACTOR VESSEL.
****

Provide ceramic construction fine bubble diffusers, of the tube, disc or dome type. Manufacture ceramic of bonded silica or alumina, and resistant to degradation by ozone in oxygen concentrations of [16] [_____] percent. Provide a maximum of [50] [_____] um [0.002] [_____] inch pore size or the manufacturer's standard pore size to produce bubbles [2] [_____] mm [0.005] [_____] inch in diameter or smaller. Provide a maximum of standard [_____] L/s cubic feet/minute gas flow per diffuser at a submergence of [_____] m feet. Limit maximum allowable headloss per diffuser to [_____] mm inch. Provide Grade TP316L stainless steel brackets, holders, bolts, rods, washers, and other accessories unless otherwise indicated. Provide silicone construction gaskets.

2.4.8 Couplings

Provide fittings, flanges, bolts, nuts and washers the same material as the piping unless otherwise indicated. Provide stainless steel sleeve type couplings for ozone service conforming with ASTM A312/A312M, Grade TP316L with ozone resistant gaskets. Comply with ASTM A53/A53M, Grade B for couplings for non-ozone ferrous metal piping.

2.4.9 Insulating Joints

Provide insulating joints when ferrous metal piping is joined with non-ferrous metal piping, fitting or valve materials. Install insulating flanges and have insulating flange gaskets, insulating sleeves for studs, and insulating washers for both sides of flanges. Install steel washers between the insulating washers and nuts. Provide couplings the same pressure rating as the pipe installed.

2.4.10 In Pipeline Static Mixers

****
NOTE: Static mixers are generally recommended to ensure complete mixing when peroxide or hypochlorite is used. Static mixers may also be needed in other processes in the treatment train; if so, coordinate and list those requirements separately or coordinate them with other specification sections to ensure there is no duplication.
****

Install in pipeline static mixers [at the locations indicated] [upstream of the reaction chamber]. [Install mixers in a flanged section of piping] [with removable mixing sections] [insert mixer into the pipeline], have a pressure rating equal to that of the piping installed, have a maximum headloss of [_____] mm inch of water, [at [_____] L/s gpm] while inducing completely turbulent mixing conditions in the pipeline installed. Construct mixers [and housing] of [Grade TP316 stainless steel] [_____] and be compatible with [hydrogen peroxide] [sodium hypochlorite] [_____]. [Port static mixer for direct application of the applied chemical.]

2.4.11 Bolts, Nuts, Anchors and Fasteners

Bolts, nuts, anchors and fasteners will be stainless steel in conformance with ASTM F593.

2.5 MANUFACTURED UNITS

****

NOTE: Design all UV systems in compliance with UFC 3-240-01 for wastewater collection and treatment.

****

Submit wiring and control diagrams, systems layouts and isometrics, component identification tables, instructions, and other sheets, prior to posting. Prepare condensed operating instructions explaining preventative maintenance procedures, methods of checking the system for safe operation, making adjustments, and procedures for safely starting and stopping the system in typed form, framed and posted beside the diagrams. Submit drawings showing shop and erection details and chemical application locations; including cuts, codes, connections, holes, bolts, welds, anchorage, installation details, wiring diagrams, schematic diagrams, component identification tables and directory, and clearances for maintenance and operations.

2.5.1 UV System

Design all UV components in compliance with ANSI C82.4 for high-intensity-discharge and low pressure sodium lamps. UV control systems need to meet the general requirements of NEMA ICS 1 for standard industrial control systems.

2.5.1.1 UV Reactor Chamber

****

NOTE: If an existing UV disinfection system with concrete channel would be converted to UV AOP system, the ozone, or hydrogen peroxide, or sodium hypochlorite needs to be injected into the channel. The existing concrete channel needs to be coated to prevent the corrosion due to the chemical injection. If the ozone is used, install the ozone gas destruction system must be installed.

****

a. Design the UV chamber with welded construction manufactured from 2205 duplex stainless steel. Pickle, passivate, and bead blaste the UV chamber for uniform external finish.

b. Design the UV chamber to handle a maximum operating pressure of [_____] kpa psig, and fully assemble and hydrostatically test UV chamber to 1.25 times the rated operating pressure, for at least 10 minutes without leakage, in the factory prior to shipment.

c. Supply each UV chamber with [_____] cm inch AWWA Class [_____] flanged inlet/outlet connections.

d. Equip each UV chamber with low pressure, high output UV lamps and each lamp in an individual quarts sleeve arranged perpendicular to the direction of flow. Install chamber horizontally or vertically.

****

NOTE: The UV lamp can be installed either horizontally or vertically and will be determined by manufacturers. The water can flow either perpendicular or parallel to the lamp. If the UV lamp is installed horizontally, the cooling is better due to UV lamp sleeves submerged but maintenance may be more complicate. If the UV lamp is installed vertically, the maintenance is easier and efficiency may be less when compared with horizontal UV lamp.

****

e. Design the UV chamber such that operating personnel at the plant can change the lamps without draining the chamber.

f. Provide the UV chamber with access ports for easy access to the quartz sleeves and cleaning system.

g. Design all piping so that the chamber will be full of water at all times. Air trapped in the chamber will result in chamber shut down to avoid overheating.

h. Reach maximum UV output for UV lamps within 5 minutes (defined as the warm-up period). If discharging water that may not have received specified dose levels during the warm-up period is not acceptable, then a separate cooling water line may be required. Cooling water is not required for chamber start-up as long as the minimum in-line flow rates are initiated within the allowable "zero flow" operation time. If it is expected that the minimum in-line flow rates cannot be initiated within the allowable "zero flow" operation time, or if the plant desires to operate the chambers in "Hot Standby" mode (i.e., the lamps are powered, but process water is not being passed through the Chamber), then cooling water is required.

****

NOTE: Applies to drinking water applications.

****

i. Certify all wetted components within the chamber to meet NSF/ANSI/CAN 61.

2.5.1.2 UV Lamps

Provide low pressure high output type UV lamps with an 141 cm 55.5 inches arc length and a maximum power input of 54.4 kW 73 hp with [_____] as the maximum number of lamps. Protect the filament to withstand shock and vibration. Provide lamp bases resistant to UV, hydrogen peroxide, and ozone. UV wave length is 254 nm. The minimum UV dose is 2,702 mJ/cm2

2.5.1.3   UV Lamp Quartz Sleeves

Manufacture the UV lamp sleeves from Type 214, fully annealed clear fused quartz tubing. Dome lamp sleeves at one end. Seal the open end of the lamp sleeve by means of an o-ring and stainless steel compression plate.

2.5.1.4   Lamp Drive

a. Provide lamp drivers of a high frequency output, fully electronic design with a minimum efficiency of 95 percent at full load, and a power factor of 99 percent or better.

****

NOTE: The range of 30 to 100 percent is recommended by manufacturers and performance guarantee is provided for this range. If the flow is variable, the output can be adjusted for energy saving. The range can be adjusted to 50 percent to 100 percent if the incoming flow does not have variable range.

****

b. Provide lamp driver with a variable operation range of 30 percent to 100 percent of full rated output and be adjustable in 1 percent increments.

c. Design the maximum allowable total current harmonic distortion (current THD) not to exceed 10 percent at the maximum power level.

d. Provide lamp driver with a mean design life expectancy of at least 10 years.

e. Rack mount drivers in the control power panel (CPP) and changeable without the use of tools.

2.5.1.5   UV Intensity Sensor(s)

a. Locate the UV Intensity Sensor(s) inside the chamber and contained within protective quartz sleeves.

b. Provide one sensor for every [_____] lamps.

c. Incorporates silicon carbide (SiC) diodes for sensor(s), and provide NIST-traceable measurement with a total absolute uncertainty of 15 percent or less at an 80 percent confidence level.

d. Meet the requirements of the EPA 815-R-06-007 for sensor(s). Filters out wavelengths below [240] nm, and provide a spectral response peaking between [250] nm and [280] nm with less than 10 percent coming from wavelengths greater than [300] nm.

e. Serialize each complete sensor assembly and the internal circuit board containing the diode.

f. Clean the quartz sensor by the mechanical wiping system.

2.5.1.6   Control Power Panel (CPP)

a. Provide one control power panel (CPP) with power distribution and lamp driver control for each UV chamber that houses all lamp drivers.

Contains a maximum of 24 lamp drivers for each CPP section (assumed with a single door).

b. Rate the CPP enclosure [NEMA 4X] [_____], ventilated with cooling suitable for indoor installation.

c. Design the CPP to operate with the following electrical supply: 480 V, 60 Hz, 3 phase, 4 wire + GND (from a grounded wye source).

d. Provide each CPP with a lockable disconnect handle that will shut down the chamber/cabinet power when the cabinet door is opened.

e. Equip the CPP with a controller which continuously monitors and controls the UV chamber's functions. Custom electronics, an input flow signal (supplied by others), and the UV sensor(s) provide the controller with the necessary indications of system parameters.

2.5.1.7 Local Control Panel (LCP)

Provide one Local Control Panel (LCP) with the UV system to control the functions of the UV-oxidation system and coordinate operation of the UV chambers. Rate the LCP enclosure [NEMA 4X] [_____]. Equip the LCP with a PLC controller which continuously monitors and controls the UV chamber functions. Custom electronics, UV transmittance and feedback from the [hydrogen peroxide] [sodium hypochlorite] [ozone] [TiO2] feed system provide the PLC with the necessary indication of system parameters.

Provide menu driven operator interface(s) that displays the following system information when prompted: chamber status, individual lamp status, lamp operating hours, contaminant log reduction, oxidant system settings, UV transmittance, UV intensity, power level, alarms, alarm history. Display the most recent alarms on the operator interface when prompted, recorded by alarm type, date and time of occurrence, and date and time of correction.

2.5.1.8 Cleaning Systems

a. Equip each UV chamber with an integrated automatic on-line sleeve cleaning system.

b. Drive the cleaning system by a hermetically sealed magnetically coupled hydraulic drive.

c. Design the drive system such that all hydraulic connections are outside the UV chamber. Use biodegradable hydraulic fluid hydraulic fluid.

d. Provide the cleaning system with mechanical cleaning abilities for the lamp and UV intensity sensor sleeves, complete with an automatically-initiated and controlled cleaning cycle. Keep UV system fully operational and treating water while cleaning.

e. Field adjust cleaning cycle intervals via the operator interface. Also provide manual cleaning system control through the operator interface.

2.5.1.9 On-line UV Transmission Monitor

a. Supply an on-line UV Transmission (UVT) monitor to automatically monitor the UVT of the process stream (measured at 254 nm, 1 cm pathlength). Provide a 70 percent to 100 percent UVT range.

b. Include a UV lamp (with expected life of 9,000 hours), UV sensor, drive system, system controller and operator interface for UV monitor that displays the system status and allows for manual on/off system control.

c. Provide UL, CSA, or CE approved, Grade TP304 stainless steel, [NEMA 4X] [_____] panel.

d. Provide 10 mm 3/8 inch female inlet/outlet fittings for connection to process stream and drain. Supply a maximum of 8 mm 1/4 inch internal diameter tubing/piping.

e. Provide a 4-20 mA output for data transmission to remote devices. Provide a discrete common alarm for remote indication of alarm condition.

f. Provide 120 Volt, 1 phase, 2 wire + ground, 15 amp power supply, 250 VA power supply to the system.

2.5.1.10 Safety Equipment

a. Equip each UV chamber with a temperature switch to prevent the chamber from overheating at temperatures above 50 degrees C 122 degrees F. Wire the temperature switch to the LCP, and shut the chamber down and initiate an alarm condition when activated.

b. Equip each UV chamber with a water level switch to prevent operation of the UV lamps in air. Wire the level sensor to the LCP and shut the chamber down and initiate a critical alarm condition if low water level is detected.

2.5.2 Swing Adsorption Oxygen Generation System

****

NOTE: Edit the following paragraphs to reflect the type of ozone generator feed gas (air or oxygen) that is included in the design package. A cost comparison should be performed prior to selecting the feed gas. Typically, oxygen in a liquid form or generated onsite from ambient air will be used. Air feed ozone generators typically produce ozone concentrations of approximately 2 percent in air, while oxygen feed systems typically produce ozone concentrations of 6 percent or greater in oxygen. VSA systems are generally used for systems that generate greater than 900 kg 2000 pounds per day.

For liquid oxygen (LOX) tanks, smaller than the minimum capacity stated in NFPA 55, state that the requirements indicated in the standard apply to the tank size specified. LOX tanks should not be located inside a treatment facility. This paragraph contains statements describing a complete manufactured unit, usually a standard catalog item; statements may include descriptive requirements for the materials, specific fabrication, finishes, and

function. Separate paragraphs for each different item should be used when appropriate.

Generally, skid mounted equipment is preferred; however, this may not be possible with larger oxygen generation units (greater than 225 kg 500 pounds per day). Verify dimensions with manufacturers to ensure the skid mounted units are transportable and do not have an excessively large space requirement over equipment that is field assembled. The following paragraphs may need to be modified to allow assembly, wiring, and plumbing in the field.
****

Provide a swing adsorption type of Oxygen Generation System. Provide [pressure swing adsorption (PSA)] [Vacuum swing adsorption (VSA)] system equipment as a complete unit process, including the compressor, [particulate filters,] [aftercooler separator,] heat exchangers, switching valves, instrument air dryer, adsorbent beds, adsorbent material, [oxygen receiver,] controller and other equipment as required by the manufacturer to provide a complete and operational oxygen generation system. [The unit] [Each component] will be completely wired requiring only [interconnecting wiring between components] [an external connection for a single external power supply and remote monitoring] [and control] be done in the field. Provide the [PSA] [VSA] system as a continuous output system with the following characteristics:

Min. oxygen generation capacity	[_____] kg/day lbs/day
Oxygen purity (minimum)	[90] [_____] percent
Temperature to generator (max.)	[30] [_____] degrees C[86] [_____] degrees F
Dewpoint maximum (below 0 degrees)	[60] [_____] degrees C[76] [_____] degrees F
Oxygen utilization efficiency (min.)(Ratio of oxygen delivered to the ozone generator/oxygen present in the air feed to the oxygen generator)	[40] [_____] percent
Cycle time (adjustable range)	[_____] minutes
Hydrocarbon concentration to ozone generator (maximum)	[0] [3] [_____] ppm
Discharge pressure to ozone generator	[_____] kPa psi
Power supply	[480] [_____] volt, 3 phase, 60 hertz.
Cooling water supply (max. temperature)	[_____] degrees C F

Cooling water flow rate (maximum)	[_____] L/s gpm

Adsorption vessels will be designed and constructed in accordance with ASME BPVC SEC VIII D1.

2.5.3   Liquid Oxygen (LOX) Storage and Supply System

****
NOTE: Provide seismic requirements for piping, tanks and related equipment supports, if a Government designer is the Engineer of Record, and show on the drawings. Delete the inappropriate bracketed phrase. Include pertinent portions of UFC 3-301-01 and Sections 13 48 73 SEISMIC CONTROL FOR MISCELLANEOUS EQUIPMENT and 23 05 48.19 [SEISMIC] BRACING FOR HVAC, properly edited, in the contract documents.
****

Comply with NFPA 55 and CGA G-4.4 for LOX storage and supply system and associated equipment. Provide tanks, vaporizers and regulators suitable for exterior installations. Accomplish cleaning for components, equipment, valves, piping and tanks for oxygen service in accordance with CGA G-4.1, CGA HB. Rate the system to withstand a minimum wind speed of [_____] km miles per hour, maximum ambient temperature [_____] degrees C F, minimum ambient temperature [_____] degrees C F, [_____] relative humidity, and [_____] meters feet mean sea level altitude. Support and brace the system to resist seismic loads [as specified in UFC 3-301-01 and Sections 13 48 73 SEISMIC CONTROL FOR MISCELLANEOUS EQUIPMENT and 23 05 48.19 [SEISMIC] BRACING FOR HVAC] [as indicated].

2.5.3.1   LOX Storage Tanks

****
NOTE: Typically, 304 stainless steel is used for LOX inner tanks less than 6000 L 1500 gallons or 6750 kg 15,000 pounds, while 9 percent nickel units are generally specified for larger tanks principally due to economic considerations. Typical maximum operating pressure for the LOX system will generally be less than 515 kPa 75 psi; significant cost savings can be achieved by reducing the tank pressure requirements, but lower pressure tanks may require a longer lead time to procure since the 1.2/1.7 MPa 175/250 psi tanks are most commonly provided.
****

Provide [_____] kg pound double walled vertical cryogenic bulk LOX storage tanks constructed in conformance with [ASME BPVC SEC VIII D1] [_____], rated for a maximum operating pressure of [1.2] [_____] MPa [175] [_____] psi and design temperature between minus 212 and plus 65 degrees C minus 350 and plus 150 degrees F, and seismic parameters defined in previous paragraph. Construct the inner wall of non-embrittling alloys [Grade

TP304 stainless steel] [9 percent nickel steel] [_____], and design, fabricate, test, inspect, and stamp in accordance with Section VIII, Division I, of the ASME Code. Construct the outer shell of carbon steel with a minimum outer shell thickness of [10] [_____] mm [0.375] [_____] inch and designed for full vacuum internal with a safety factor not less than two (minimum collapse pressure of 30 psi) and to support the inner vessel. No code stamp is required for outer vessel. Insulate annular area between the inner and outer walls to limit oxygen boil off rate to less than [0.25] [_____] percent of the tank capacity per day at the maximum ambient conditions. Provide copper or Grade TP316 stainless steel piping. Provide bronze or Grade TP316 stainless steel fittings.

2.5.3.1.1 Storage Tank

Provide the liquid oxygen storage tank with a mounting base complete with Grade TP316 stainless steel anchor bolts. Provide hot dipped galvanized or painted A36 carbon steel support framing for the storage tank and bolt to the tank in a manner to preserve the continuity of the galvanizing. After assembly, cold galvanize areas of disturbed or damaged galvanizing. Inner vessel pressure relief system include two safety relief valves, two rupture discs, and a selector valve, in accordance with ASME Code, Section VIII. Outer vessel pressure relief consists of an automatic relief device. Provide perlite packing insulation in the annular ring and a high vacuum or vacuum super-insulation not exceed 0.3 percent of the tank capacity by weight per day for the tank boil off rate at the maximum ambient conditions. Size anchor bolt by the tank supplier.

2.5.3.1.2 Economizer

Equip the tank with an economizer system to direct the boiled off gaseous oxygen to the ozone generation feed gas system rather than venting to atmosphere. Design the tank such that the pressure leaving the system is not less than 276 kPa 40 psig. Equip the tank with a pressure building system if required to maintain the minimum pressure for all operating conditions. Provide Grade TP316 stainless steel internal piping and fittings with welded connection. Provide Type K copper external piping with wrought copper fittings. Provide all bronze construction valves. Provide extended stems and bonnets for liquid valves. Include a dip tube liquid withdraw system, a vapor return line from the economizer system, a level transmitter, a pressure indicator/transmitter, and both top and bottom fill capability for tank. Fit lines with quick connect couplings for tanker truck delivery of the liquid oxygen.

2.5.3.1.3 Grounding

Provide each liquid oxygen tank with two ground pads for attachment to 3/0 copper ground cables terminated with NEMA two-hole copper compression ground lugs. Locate ground pads on tank supports at opposite corners of the tank and install approximately 0.6 m 2 feet above grade.

2.5.3.1.4 Signage

Provide the tanks with hazardous material signal arrangements permanently affixed on both sides following field painting. Each signal arrangement is a 125 mm by 125 mm 5 inches by 5 inches diamond shaped background painted white. Paint the health signal blue, paint the flammability signal red, and paint the reactivity signal yellow. All signals are 50 mm 2 inches high. In the diamond shaped signal arrangement, identify the health signal at the left, identify the flammability signal at the top, identify the reactivity signal at the right, and use the bottom to identify special hazard. Give the following numerical gradings to the signals: Health - "3", Flammability - "0", Reactivity - "0" and Identify - "OXY" as a special hazard.

2.5.3.1.5 Control

Provide a LOX control panel for the LOX storage system. Equip the control panel with a NEMA 4X [_____] enclosure to house instrumentation, control, and telemetry systems. Supply the power to panel from a single 120-Vac, 20A circuit. Power all instrumentation, control, and telemetry systems from this circuit. Single point of connection for client wiring including power, control, and instrumentation signals. Provide terminal blocks for interface wiring. Equip LOX System with a telemetry system for remote monitoring of the tank level and other points as required by LOX Supplier. [Supplier needs to monitor and utilize information to automatically schedule bulk deliveries based on LOX level remaining in the tank. Provide client access to view the information from the telemetry system via a web-based interface operated by the LOX Supplier.] Provide front panel displays for level and pressure transmitters. Maintain enclosures NEMA rating for displays. Provide front panel indicator lights and controls for low vaporizer temperature and vaporizer selection valves. Include indication for valve closed and valve opened and open/close control for valve indication and control. Provide a red, mushroom head style emergency stop push button on the front of the control panel and interlock with client's remote emergency stop signal for closure of emergency shut-off valve. Any above ground conduit required is Rigid Aluminum Conduit (RAL) or Liquid Tight Flexible Metal Conduit (LTFMC), unless approved by Contracting Officer prior to installation. All conduits are minimum 20 mm 3/4 inch except where 15 mm 1/2 inch is required to match instrument hubs. Install electrical in accordance with the latest edition of NFPA 70.

2.5.3.2 Vaporizers

****

NOTE: Vaporizers should be designed for the anticipated flow rate to the ozone generator. If vaporizers are oversized, gas temperatures will reach outside ambient temperatures, resulting in higher oxygen gas temperatures during the summer months being fed to the ozone generator, reducing its efficiency. Normal operating pressure for an ozone generator is approximately 103 kPa 15 psi. Resulting pressure at the diffusers is approximately 103 kPa 15 psi less system losses.

In cold climates, heaters may be required to warm the oxygen gas feed to the ozone generator. The actual heating requirements should be coordinated with the ozone generator manufacturer. In cases where ambient temperatures fall below freezing for extended periods, supplementary heating may be necessary.

LOX systems may require a small quantity of nitrogen gas be added to the feed stream to facilitate ozone gas flow through the generator. This may be accomplished by adding a small volume of dried

ambient air (about 2 percent).
****

2.5.3.2.1   Vaporizer Equipment

Consist of a minimum of [2] [3] ambient air vaporizers and [single] [double] regulator system complete with automatic switching and a manual bypass. Rate each vaporizer for 100 percent capacity, under continuous operation at a [_____] cubic meters/second SCFM withdrawal rate and also capable of supplying a peak withdrawal rate of [_____] cubic meters/second scfm. Design the vaporization equipment for an inlet pressure of [_____] kPa psi, and a maximum headloss between the tank and ozone generator of [_____] kPa psi. Provide extra wide spacings for the vaporizer extrusions between the individual extrusions with a minimum area per extrusion of [1.65] [_____] square meters/meter [5] [_____] sf/ft. [Provide heaters to automatically warm the oxygen feed gas to the ozone generator when the oxygen feed temperature falls to less than [_____] degrees C F. Ensure heaters capable of warming the oxygen feed gas to a temperature range between [10 and 22] [_____] degrees C [50 and 72] [_____] degrees F]. Operate each vaporizer for a minimum of [8] [_____] hours at the minimum ambient conditions and continuous withdrawal rate specified. The defrost cycle for each vaporizer be a maximum of [8] [_____] hours at the minimum ambient conditions and continuous withdrawal rate specified. Insulate piping between the LOX tank and ozone generator as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

Fabricate vaporizers from aluminum, factory-assembled unit complete with appropriate manifolds to minimize pressure drop, bracing, lifting lugs, safety appurtenances, necessary internal manifolding, and to be suitable for outside installation and operation. The materials of construction are suitable for the design conditions, are oxygen compatible and, are factory cleaned for oxygen service and sealed. Install inlet and outlet nozzles no more than 1.52 m 5 feet above floor level. Both nozzle dimensions need to meet ASME B16.5 flange requirements.

2.5.3.2.2   Grounding

Provide each vaporizer with two ground pads for attachment to 3/0 copper ground cables terminated with NEMA two-hole copper compression ground lugs. Locate ground pads on vaporizer supports at opposite corners of the vaporizer unit and install approximately 0.6 m 2 feet above grade. Provide a minimum of four steel lifting lugs to lift the units. Size anchor bolt sizing by the ambient vaporizer supplier. Design vaporizers for the design criteria as specified with normal frost load. Provide extended gap between extrusion fins for ice accumulation.

2.5.3.3   LOX Usage and Feed Gas Flowrate

2.5.3.3.1   LOX Supply and Delivery

For LOX supply and delivery, the total average annual usage is estimated to be between [_____] and [_____] scm/year scf/yr. The LOX system is able to meet the following oxygen flow rate criteria under all temperature conditions at site:

a. Minimum: [_____] SCMH, SCFH

b. Average: [_____] SCMH, SCFH

a. Maximum: [_____] SCMH, SCFH

2.5.3.3.2 LOX Feed Gas Flowrate

At a minimum, meet the requirements of AWWA B304 and the quality requirements of the OSS for LOX feed gas flowrate. Include the following qualified requirements from the OSS:

a. Supply the dew point of the LOX not higher than -65 degrees C -85 degrees F at standard atmospheric pressure.

b. Deliver 98 to 100 percent (mole/mole) purity of the LOX oxygen.

c. Less than 20 ppmv hydrocarbons (as CH4) in LOX.

2.5.3.3.3 LOX Quality

LOX is free from freons and solvents. LOX deliveries need to include an affidavit of compliance that contains:

a. The guaranteed dew point temperatures (at standard atmospheric pressure) of each individual shipment. Supply temperatures in degrees Celsius and degrees Fahrenheit.

b. Total hydrocarbons (THC) of the individual shipment. State THC in parts per million (ppm) and is in compliance with the above information.

c. The grade of the LOX delivered at each individual shipment. Specify the purity level of each individual shipment as a percentage (mole/mole) and comply with the above information.

2.5.3.4 Regulators

Factory test regulators with outlet pressure field adjustable over a downstream pressure range from [69 to 172] [_____] kPa [10 to 25] [_____] psi, from 0 to 100 percent of the specified oxygen flow rate. Rate regulators at 1030 kPa 150 psi, and constructed of Grade TP316 stainless steel.

2.5.4 Ozone Generator Air Feed System

Provide system equipment which processes ambient air directly as the ozone generator feed gas by a single supplier, [be of the pressure swing type and] include an air compressor and receiver, aftercooler, [refrigerative dryer], vapor/liquid separator, [coalescing and] [particulate] filters, desiccant air dryer, particulate after filter, switching valves, pressure, temperature and moisture monitors, local controller and other equipment as required by the manufacturer to provide a complete and operational air preparation system. [Provide skid mounted equipment.] Design and construct adsorption vessels in accordance with ASME BPVC SEC VIII D1. Provide [activated alumina] [_____] adsorption material. Provide a completely wired unit requiring only an external connection for a single external power supply and remote monitoring [and control]. Provide a continuous output air preparation system with the following characteristics based on 100 percent relative humidity and maximum ambient temperature of [_____] degrees C F:

Minimum dry air feed to ozonator	[_____] cms scfm/m
Operating pressure at stated capacity	[345] [_____] kPa[50] [_____] psi
Pressure drop through desiccant dryers (maximum)	[20] [_____] kPa[3] [_____] psi
Maximum air temperature to ozone generator	[30] [_____] degrees C[86] [_____] degrees F
Maximum dewpoint (below 0 degrees)	[60] [_____] degrees C[76] [_____] degrees F
Maximum hydrocarbon concentration	[0] [1] [_____] ppm
Discharge pressure to ozone generator (min)	[_____] kPa psi
Cycle time adjustable range	[1 to 5] [_____] minutes
Power supply	[480] [_____] volt, 3 phase, 60 hertz

2.5.5 Ozone Generator System

****

NOTE: Delete this paragraph if an ozone generator is not used. Horizontal tube, medium frequency generators are the most common; however, since the state of the art is constantly changing, verify that other types of generators are not available or appropriate for the particular application.

Coordinate pressure requirements with paragraph Ozone Generator Air Feed System. Typical pressure ranges required for ozone systems are dependant upon the final ozone outlet pressure, generally between 69 and 103 kPa 10 and 15 psi plus losses through the equipment.

****

Provide continuous duty water cooled, multi-tube glass or non-glass multitube dielectric [horizontal tube] [vertical tube] assemblies for ozone generation equipment contained in a pressure vessel [with hinged gas-tight doors] with a rated design pressure of [_____] kPa psi. Provide each unit with [medium] [high] frequency electrical power supply units including input and output transformers, power controller, frequency inverter, harmonic mitigation equipment (if required). Provide the generator with complete controls, [compatible with the central control unit,] instrumentation, panels, appurtenances and miscellaneous equipment required for a complete ozone generating system using [oxygen] [air]. Provide all equipment, valves, piping, associated appurtenances suitable for ozone in [oxygen] [air] service. Generator design requirements are as follows:

Capacity	[_____] kg lbs/day
Gas flow rate to generator	[_____] cms scfm
Outlet pressure ± 5 percent)	[_____] kPa psi
Ozone concentration	[_____] percent
Generator vessel design pressure	[_____] kPa psi
Ozone output concentration turn down	[10:1] [_____]
Cooling water temperature rise at rated production capacity (maximum)	[3] [_____] degrees C[5] [_____] degrees F
Carrier gas rise across generator (max.)	[30] [_____] degrees C[17] [_____] degrees F
Inlet hydrocarbon concentration (max)	[0] [_____] ppm
Power supply	[480] [_____] volt, 3 phase, 60 hertz

Build all ozone generating vessels, regardless of physical size, volume or operating pressure to ASME Sect. VIII, Div. 1 Code guidelines for unfired pressure vessels and supply with "U" stamp rating for 50 psig or higher. Locating the ozone generating vessel(s) inside a cabinet or other enclosure does not relieve the contractor from this requirement. Do not consider and accept guidelines other than ASME Sect VIII, Div. 1. Do not create spurious harmonics for the ozone generators. Furnish filters to prevent power harmonics and meet the latest IEEE 519 Standards. Draw equal currents for the ozone generator from all three phases to prevent unbalancing of the power lines. Isolate the ozone generating vessel to allow an immediate high voltage disconnect in case of a dielectric failure. If dielectric failure and disconnect occur, continues to function generator with the remaining dielectrics. Install a high voltage fuse for each row of dielectrics to create a disconnect from the high voltage grid located inside the ozone generator.

2.5.5.1 Ozone Generator Vessels

Construct all ozone generator metal parts that come into contact with ozone or cooling water of Grade TP316l stainless steel. Design the vessel to resist an internal pressure of 1.5 times the design pressure, including the tubes and shell. Provide over pressure protection based on worst case operating conditions. Construct the vessels in accordance with ASME BPVC SEC VIII D1 code. Provide viewing ports to allow visual inspection of all internal dielectrics during operation.

2.5.5.2 Dielectric Tubes

Construct dielectric tubes to resist thermal shock and to evenly distribute the applied electrical charge over the entire dielectric surface without arcing. Form dielectric tubes from either glass or a non-glass material with a certified voltage breakage strength of 1.5 times the maximum possible operating voltage under maximum temperature and applied power conditions. Protect dielectric tubes by fuses or functionally equivalent devices to prevent shorting dielectric tubes from damaging the shell and tube structure in the ozone generator.

2.5.5.3   System Protection

Provide the ozone generator with circuitry and appropriate sensors to prevent the following:

a. Brown outs, black outs and power surges

b. Phase failure

c. Excessive temperature

d. Opening the ozone generator cabinet while it is in operation

Size a main power circuit breaker to protect the ozone generator. Provide a mechanical pressure relief valve to prevent excessive pressure build-up in the ozone generating vessel PLC controls start-up and shut-down operations, diagnostic, and timing functions etc. Furnish the ozone generator skid with all the components pre-piped, and prewired and tested at the factory. Not less than 1 percent by weight for the minimum concentration of ozone in the generator exit.

2.5.5.4   Power Supply Unit (PSU)

Contain its own transformer and frequency inverter for each PSU. Provide dry type high voltage transformer rated at least 10 percent above the maximum anticipated KVA. Design the secondary voltage so as to prevent dielectric failure due to high voltage. Control each PSU by its own local control panel, or by the local control panel (LCP) located on the generator skid. Automatically control power supply to ozone generator to satisfy ozone mass flow rate set points for the ozone system using constant concentration control. Hold the ozone-in-oxygen concentration constant at an initial concentration set point of 10 percent, which is adjustable from 6 to 12 percent, while varying the gas flow rates to the ozone contactor to satisfy ozone mass flow required to meet a preset ozone residual. Permit the power supply unit with the following operations:

a. Activate/deactivate the ozone generator unit from the front panel touch screen or from a remote location.

b. Allow the selection of MANUAL or AUTOMATIC control of ozone output.

c. Automatic ozone output control from a 4-20 mA signal based on the ozone residual.

d. Turndown to 10 percent of ozone rated output either in manual or automatic mode.

PSU characteristics and requirements

Characteristics	Requirement	Notes
Quantity	[_____]	
Enclosure	NEMA 4X [_____]	
Input	[_____] V, [_____] Jz. [_____] Phase	
Power consumption	[_____] kwh/kg kwh/lb	
Power factor	>0.95	
Harmonic Integration	Meet or exceeds IEEE 519 standard	
Cooling method	Closed loop	Water only; glycols and oils are not acceptable; NSF 61 approved corrosion inhibitors are acceptable. Integrate cooling water system to the Ozone Generator skid.
Control Method	Constant Concentration	Flow rates can be adjusted to reach target residual ozone concentration set by the Owner

2.5.5.5 Cooling Water System

Monitor and control by the local control panel (LCP). Furnish the cooling water system with Grade TP316L stainless steel plate and frame heat exchanger, centrifugal horizontal pump with TEFC motor, an expansion tank, a chemical pot feeder, an air water separator and all instruments and valves required for successful operation of the system. Size each cooling water system by the OSS to deliver sufficient water to one ozone generator and power supply unit loop cooling not to exceed -13 degrees C 9 degrees F for the differential temperature of the open loop cooling.

2.5.6 Ozone Destruct System

****

NOTE: High concentrations of chlorinated organics may be liberated by systems that use ozone in air or oxygen. These chlorinated organics may "poison" a catalyst bed designed only for ozone destruction. If considerable concentrations of chlorinated organics are anticipated (greater than 1000 ppm) in the reactor off gas, a chlorine resistant catalyst should be specified or a separate specification section should be used.

****

Each ozone off gas destruction equipment with thermal assisted catalyst destruct type units suitable for moist ozone in [oxygen] [air] service. Construct the catalyst containment unit, piping, ductwork, and other metallic components of Grade TP316 stainless steel. Provide the units capable of destroying contactor off gas generated by the ozone generators which feed the AOP reactors. Have the capability for the ozone destruction unit to function at a minimum turn down ratio of 20 to 1. Provide a skid mounted unit for each off gas destruction unit consisting of [a demister,] an electric resistance heater, catalyst trays and containment vessel [, and a centrifugal blower]. Stop the destruction unit discharge duct away from the destruct unit to reduce the probability of catalyst fouling from condensation. Slope ducts carrying ozone laden off gas from the AOP reactors to a low point valved drain located upstream of the ozone destruct system. Reduce the ozone concentration by the ozone destruct system from the off gas flow to less than [0.10] [_____] ppm by volume of ozone from zero flow to the maximum off gas flow rate. Define normal operation as [50] [_____] percent of the maximum off gas flow rate with an ozone concentration of [1.0] [_____] percent by weight. Design ozone destruction equipment to meet the following requirements:

Maximum pressure drop through catalyst at maximum flow rate	[_____] mm of mercury[_____] inches of water
Maximum pressure drop through heater at maximum flow rate	[_____] mm of mercury[_____] inches of water
Maximum off gas relative humidity	[_____] percent
Max. temperature rise across heater	[20] [_____] degrees C[35] [_____] degrees F
Catalyst chamber empty bed contact time	[1.0] [_____] seconds
Max. ozone concentration into destruct unit	[1.0] [_____] percent by weight
Off gas flow rate (maximum)	[_____] cubic m/sscfm
Maximum catalyst bed temperature	[120] [_____] degrees C[250] [_____] degrees F
Off gas temperature to catalyst bed	[15] [_____] degrees C[60] [_____] degrees F
Power supply	[480] [_____] volts, [3] [_____] phase, 60 hertz

Provide catalyst with non-hazardous [manganese dioxide/copper oxide] [nickel] [_____] based material suitable for catalytic ozone destruction at the specified conditions. Provide the catalyst containment unit with a flanged and bolted top or hatch a minimum of 300 mm 12 inch in diameter to facilitate change out of the catalyst material when the catalyst is exhausted.

2.5.7 Hydrogen Peroxide Storage and Feed System

****

NOTE: Edit Section 46 30 00 WATER AND WASTEWATER CHEMICAL FEED SYSTEMS to provide on-off, set point, or proportional control as appropriate.

Hydrogen peroxide storage system requirements should be coordinated with suppliers to ensure material compatibility. Floating roof manway area should equal 1 in 2 per 400 L 100 gallons for solutions less than 52 percent, and 2 in 2 per 400 L 100 gallons for solutions greater than 52 percent. Follow process safety management requirements any time more than 3375 kg 7500 pounds of H2O2 is stored, or the solution strength is greater than 52 percent; refer to 29 CFR 1910.119 for information.

Hydrogen peroxide storage tanks should be located outside when possible. Polyethylene should not be used for peroxide concentrations greater than 52 percent.

****

Construct the hydrogen peroxide storage tank of cross linked polyethylene, Grade TP316 stainless steel, or 99.5 percent pure aluminum alloys designated in ASTM B209/B209M as 1060, 5254, 5652. Provide hydrogen peroxide storage tanks with secondary containment [as detailed on the drawings] [_____] with a minimum capacity equal to [110] [_____] percent of the maximum storage tank volume. Equip hydrogen peroxide storage tanks with [50] [_____] mm [2] [_____] inch female quick fill connection; [600] [_____] mm [24] [_____] inch hinged, weighted and gasketed manway cover; [50] [_____] mm [2] [_____] inch filtered breather vent; liquid level site tube; and [600] [_____] mm [24] [_____] inch free floating roof manway cover. Flange all piping connections. Conform feed pumps to meet the requirements of Section 46 30 00 WATER AND WASTEWATER CHEMICAL FEED SYSTEMS.

2.5.8 [Sodium] Hypochlorite Storage and Feed System

****

NOTE: Edit Section 46 30 00 WATER AND WASTEWATER CHEMICAL FEED SYSTEMS to provide on-off, set point, or proportional control as appropriate.

Hypochlorite storage system requirements should be coordinated with suppliers to ensure material compatibility.

Hypochlorite storage tanks should be located outside when possible.

****

Construct the [sodium] hypochlorite storage tank of cross linked polyethylene or fiberglass designated in [ASTM B209/B209M] [ASTM D2584]. Provide hypochlorite storage tanks with secondary containment [as detailed on the drawings] [_____] with a minimum capacity equal to [110] percent of the maximum storage tank volume. Equip [sodium] hypochlorite storage tanks with 50 mm 2 inch female quick fill connection; 600 mm 24 inch hinged, weighted and gasketed manway cover; 50 mm 2 inch filtered breather vent; liquid level site tube; and 600 mm 24 inch free floating roof manway cover. Flange all piping connections. Conform feed pumps to the requirements of Section 46 30 00 WATER AND WASTEWATER CHEMICAL FEED SYSTEMS.

2.5.9 Redox Potential Meter

Provide the oxidation reduction (redox) meter [where indicated on the drawings] [on the effluent line of each reactor]. Remove probe easily without interrupting service. Design probe materials resistant to ozone as well hydrogen peroxide attack over a pH range of 2 to 12 and operating pressures of up to [_____] kPa psi and suitable for a temperature range from [0 to 100] [_____] degrees C [32 to 212] [_____] degrees F and suitable for the medium monitored. Transmit output by probe to an ORP analyzer with digital output. Transmit a [[4 to 20] [_____] mA signal proportional to the ORP] [direct digital reading] by the ORP analyzer to the central control unit.

2.5.10 pH Probe

Provide pH probe [where indicated on the drawings] [on the effluent line of each reactor]. Ensure easily removable probe without interrupting service. Design probe material resistant to [ozone] [hydrogen peroxide] [sodium hypochlorite] attack over a pH range of 0 to 14 and operating pressures of up to [_____] kPa psi and suitable for a temperature range from [0 to 100] [_____] degrees C [32 to 212] [_____] degrees F and suitable for the medium monitored. Transmit output by probe to a pH analyzer with digital output. Transmit a [[4 to 20] [_____] mA signal proportional to the pH] [direct digital reading] by the pH analyzer to the central control unit.

2.5.11 Ozone Monitors

2.5.11.1 Vapor Phase

Provide separate ozone monitors to monitor ozone in ambient air, [at the locations shown on the drawings,] determining the ozone levels downstream of the off gas ozone destruct system, [and the ozone concentration in the ozone generator discharge]. Locate ambient air monitoring unit intake located [within 455 mm 18 inches above the treatment plant floor] [at the location shown on the drawings] [adjacent to the AOP process equipment]. Interlock the ambient air monitors with the ozone generation system to initiate an alarm condition, and ozone generator shut down when readings exceed preset levels. Provide [4 to 20 mA] [direct digital] output ultraviolet adsorption photometer type analyzers with built in pressure and temperature compensation. Have a minimum of five separate for ozone off gas monitor ranges to monitor concentrations between [[0 to 15] [_____] percent,] [[0 to 99,000] [_____] ppm by volume]. Have a minimum of five separate ranges for ambient ar and off gas destruct monitors to monitor concentrations between [0 to 10] [_____] ppm. Provide each monitor with a built in digital ozone concentration readout at the unit.

2.5.11.2 Liquid Phase

Provide liquid phase monitors [where indicated on the drawings] [on the effluent line of the last reactor vessel]. Transmit output by sensor to an ozone analyzer with digital display and remote signal transmission to the central control unit. Transmit output by probe to a liquid phase ozone analyzer with digital output. Transmit a [[4 to 20] [_____] mA signal proportional to the ozone concentration] [direct digital reading] by the liquid phase ozone analyser to the central control unit.

2.5.12 Temperature Sensors

Provide dual switch trip point independently adjustable type temperature sensors with a minimum accuracy of 0.5 percent of full scale. Construct thermal system of Grade TP316L stainless steel. Design temperature range from [0 to 100] [_____] degrees C [32 to 212] [_____] degrees F and suitable for the medium monitored. Transmit output by sensor to an analyzer with digital output. Transmit a [[4 to 20] [_____] mA signal proportional to the temperature] [direct digital reading] by the analyzer to the central control unit.

2.5.13 Compressors

Design air compressors to conform to CAGI B19.1. Factory package [rotary screw] [centrifugal] [rotary] [reciprocating] type air compressor units. Package air compressors in an enclosure with sound attenuating properties which allow a maximum noise level measurement of 75 dBA at the equipment enclosure. Cool and rate air compressors with [water] [air] for continuous operation. Shield exposed moving parts by guards. Design compressor motors and starter to conform with the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Have the manufacturer's name and address for air compressors, together with trade name, and catalog number on a nameplate securely attached to the equipment. Include any special maintenance instructions (required before startup or shutdown) in the Operations and Maintenance Manuals. Equip compressor equipment used for processing ambient air for the ozone generator feed gas with the air compressor, receiver with automatic condensate drain, intake air filter and silencer, after cooler, a high efficiency moisture separator, [refrigerative dryer], pressure, temperature and moisture monitors, local controller and other equipment as required by the manufacturer to provide a complete and operational oil free, dry compressed air system. Design compressor receivers, air piping, valves and appurtenances unless otherwise specified, in conformance with Section 40 05 13 PIPELINES, LIQUID PROCESS PIPING. Provide dry contacts and 4 to 20 mA signals in the control panel for remote monitoring.

Minimum capacity	[_____] cms scfm
Operating pressure at stated capacity	[345] [_____] kPa[50] [_____] psi
Maximum air temperature to PSA/VSA system	[30] [_____] degrees C[86] [_____] degrees F
Maximum dewpoint to PSA/VSA system (below 0 degrees)	[60] [_____] degrees C[76] [_____] degrees F
Maximum hydrocarbon concentration	[0] [_____] ppm

Cycle time adjustable range	[1 to 5] [_____] minutes

2.5.14 Blowers

Design blowers to conform to [_____]. Provide dry contacts and 4 to 20 mA signals in the control panel for remote monitoring.

2.5.15 Dew Point Monitor

Provide a solid state design for dew point transmitter housed in a [NEMA 4X] [_____] enclosure as defined in NEMA 250, with an accuracy of plus or minus 3 degrees C over an operating ambient temperature range of minus 10 to plus 60 degrees C, over a dew point range of minus 110 to plus 10 degrees C. Receive the signal by the transmitter from the thin film aluminum metal oxide sensor, convert and send it as a [single 4 to 20 mA DC signal proportional to the dewpoint level] [direct digital reading] to the central control unit. Transmit output by sensor to an analyzer with digital display.

2.5.16 Pressure Gauges

Provide glycerine filled water pressure gauges conforming to the requirements of ASME B40.100.

2.5.17 Sampling Ports

Provide aqueous and gas phase sampling ports [where indicated on the drawings] [upstream and downstream of each reactor vessel]. Provide sampling ports at locations accessible to plant operators. Construct ports and associated piping of [6] [12] [_____] mm [1/4] [1/2] [_____] inch minimum diameter [PVDF] [Grade TP316 stainless steel] [teflon] [_____] with [PVDF] [Grade TP316 stainless steel] [_____] [NPT x hose] ball valves.

2.5.18 Gas Flow Meters

****

NOTE: Numerous meters may be required which may necessitate a table be included identifying the flow capacity for each unit.

****

Equip flow meters for ozone or oxygen applications with stainless steel body, tube, valves, floats, and knobs with glass windows. Rate flow meter for a flow rate of [_____] cms scfm at a minimum pressure of [345] [_____] kPa [50] [_____] psi. Provide each flow meter with a separate stainless steel valved connection for ease of maintenance. Equip each pipe penetration through the reactor wall serving a single ozone diffuser or bank of diffusers with a flow meter. Also equip the [air] [oxygen] feed stream to the ozone generator with a flow meter. Have an easily readable scale in cms scfm for each flow meter with a minimum of ten divisions from zero to 150 percent of the expected flow through the meter. Provide each meter with an analyzer which receives the signal from the flow meter transmitter, converts and sends it as a [single 4 to 20 mA DC signal proportional to the flow rate] [direct digital reading] to the central control unit. Transmit output by sensor to an analyzer with digital display.

2.5.19 Level Monitoring

Provide pressure type level sensors, associated analyzers and transmitters for each liquid process tank associated with the AOP system. Ensure sensor element removable for servicing or replacement without taking the tank out of service. As a minimum, equip the following tanks with level monitoring equipment: [reactor vessels,] [hydrogen peroxide storage and feed tanks,] [hypochlorite storage and feed tanks] [equalization tank,] [effluent storage and equalization tanks,] [_____]. Provide solid state design for each level control element constructed of materials compatible with the liquid stored. Provide each controller with an analyzer which receives the signal from the level sensor, converts and sends it as a [single 4 to 20 mA DC signal proportional to the liquid level] [direct digital reading] to the central control unit.

2.5.20 Reactor Vessel

****

NOTE: Indicate penetration requirements, if a packing support is required; view ports; site glasses; or material options to stainless steel reactors. Also include access requirements for removal and maintenance of diffusers. Coordinate unique concrete material ozone resistance requirements with Section 03 30 00 CAST-IN-PLACE CONCRETE if concrete reactor vessels are used.

Reactors for ozone-peroxide systems, where either the ozone or hydrogen peroxide dose is not expected to exceed 25 ppm, may be constructed of fiberglass if appropriate resins are used. Coordinate with tank suppliers regarding specification requirements.

****

Provide [circular] [rectangular] reactor vessel, fabricated of [Grade TP316L stainless steel] [concrete conforming to Section [03 30 00 CAST-IN-PLACE CONCRETE] [_____] provided with [_____] mm inch, [_____] kPa psi flanged connections.] Have a minimum water depth above the diffusers of [6] [_____] m [18] [_____] feet for reactor vessels, with a minimum free board water depth above the liquid level of 600 mm 2 feet. Design [reactor to accommodate a vacuum of [25] [_____] mm [1] [_____] inch applied to the reactor headspace.] Perform welding in accordance with AWS D1.1/D1.1M by welders certified to have passed qualification tests using procedures covered in AWS B2.1/B2.1M or ASME BPVC SEC IX. Equip reactors with openings required to ensure maintenance and installation/removal of the following equipment: liquid inlets and outlets, gas inlet supply and off gas collection points, sampling connections, [pH probe], [redox meter], [level switch], site glass liquid level indicator, and other connections as indicated or required. Equip reactor vessels with a minimum of [one] [_____] viewing port no smaller than [0.5] [_____] m [1.5] [_____] feet located [0.7] [_____] m [2] [_____] feet minimum above the bottom of the reactor. Cover the viewing port with clear plastic material not susceptible to ozone degradation, with a minimum thickness of [10] [_____] mm [3/8] [_____] inch.

2.6 ELECTRICAL

Design electrical products in accordance with Section 26 20 00 INTERIOR

DISTRIBUTION SYSTEM. Independently ground UV reactor chambers containing ultraviolet lamps.

2.6.1 Motors

Provide and install motors, all motor starters, and any control or signal wiring required for the operation of the specified equipment under this section in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM unless otherwise specified herein, in other sections, or indicated on the drawings.

2.6.2 Local Controls and Panels

Provide manual or automatic controls, protective or signal devices required for the operation specified, and any control wiring required for controls and devices. Design enclosures for local power and control panels to conform to NEMA ICS 6.

2.6.3 Ultraviolet Equipment Electrical Requirements

a. Provide a separate prewired power panel for each module.

b. Provide standard ground fault detection or independent ground with the UV lamp equipment.

c. House control and monitoring components in NEMA enclosures. Seal internal components from the environment. House system electronics used in an interior environment in enclosures conforming to NEMA 250 TYPE 12. House system electronics used in an exterior and corrosive environment, as defined in NEMA 250, in enclosures conforming to NEMA 250 TYPE 4X.

d. Protect wiring and electrical connections against moisture and corrosive gases to prevent electrical shorts or failure. Make electrical installation and material to conform to NFPA 70. Completely wire the unit requiring only an external connection for a single external power supply and remote monitoring and control.

e. Provide interconnecting, multiconductor, unshielded cables suitable for outdoor installation. Provide thermoplastic rubber insulation with an operating range of minus 60 to 125 degrees C minus 75 to 260 degrees F with low temperature flexibility and flame retardants. Provide UV stabilized jacketing resistant to oils, chemicals, fuels, solvents, and to mechanical abuse and abrasion. Supply cable by the equipment manufacturer sufficient length and number for a complete system.

f. Provide 1.98 or 1.59 mm 14 or 16 gauge thick stainless steel cableways.

2.7 AOP CONTROL SYSTEM

****

NOTE: Delete items within this paragraph that do not apply. Hydrogen peroxide or sodium hypochlorite monitoring on all but very large plants (larger than 5.7 ML/day 1.5 MGD) will consist of tank level readings and an indication that the chemical feed pump is working. Coordinate with paragraph Alarms and Interlocks if separate audible or visual alarms

beyond the control system specified are required, and their location.

If an autodialer is required, reference Section 40 60 00 PROCESS CONTROL; or if none is included and an autodialer is required, include those requirements in this paragraph.

****

Locally control equipment capable of receiving standard digital or analog control signals from the plant central control system. Provide status and adjustments to the equipment [locally] [and] [from the plant central control system]. Provide instruments with mounting hardware as appropriate. Provide transmitters with digital outputs accurate to within [_____] percent. Design all equipment for operation on a 120 volts 60 hertz electrical input. Provide controls to remotely monitor [and adjust] [hydrogen peroxide [sodium hypochlorite] delivery rate,] [oxygen] [air] [and ozone output,] [_____] [individual lamp failure,] [power on and off status for each lamp [ballast]] [ultraviolet lamp intensity].[Provide each lamp with a nonresettable elapsed time meter with ability to record operable hours from 0 to 99,999].

2.7.1 Ozonation Control System

Interface the ozonation control system with the plant central control system. Accomplish changes to the ozone generator equipment operating conditions locally or from the master control panel. Provide power, control and instrumentation system as specified or as recommended by the ozone generator manufacturer for safe operation and supervision of the ozone generator and related gas feed equipment. Provide schematics and interconnecting wiring diagrams for power, control, and instrumentation circuits. Provide control power transformers, relays, adjustable timers, auxiliary contacts, switches, or additional equipment to interconnect the generator to other auxiliary equipment and master control panel, and control circuits as shown on schematic or instrument control drawings. Provide an emergency stop button at the local generator control panel. Protect the ozone generator from power surges, and variations in power supplied to the equipment.

2.7.2 Hydrogen Peroxide Feed

****

NOTE: Hydrogen peroxide metering rate is generally done manually with an interlock to shut the system down when a flow switch or other interlock at the AOP master control indicates a flow interruption. If a variable flow rate is anticipated, although rarely used, the hydrogen peroxide feed rate can be tied to the influent meter or AOP master control. Coordinate operation with Section 46 30 00 WATER AND WASTEWATER CHEMICAL FEED SYSTEMS.

****

Conform hydrogen peroxide feed pump and control to the requirements of Section 46 30 00 WATER AND WASTEWATER CHEMICAL FEED SYSTEMS.

2.7.3 Hypochlorite Feed

****

NOTE: Hypochlorite metering rate is generally done manually with an interlock to shut the system down when a flow switch or other interlock at the AOP master control indicates a flow interruption. If a variable flow rate is anticipated, although rarely used, the hypochlorite feed rate can be tied to the influent meter or AOP master control. Coordinate operation with Section 46 30 00 WATER AND WASTEWATER CHEMICAL FEED SYSTEMS.

****

Conform hypochlorite feed pump and control to the requirements of Section 46 30 00 WATER AND WASTEWATER CHEMICAL FEED SYSTEMS.

2.7.4 Alarms and Interlocks

****

NOTE: Delete items in this paragraph that are not required.

Coordinate this paragraph with process and instrumentation diagrams (PIDs) and other specification sections. Metering accuracy for hydrogen peroxide is generally done manually. Indicate if separate audible or visual alarms beyond the AOP master control system are required, and their location.

****

Provide alarms and interlocks to ensure proper operation of the advanced oxidation equipment, and its sequenced shutdown based on potentially unsafe or improper conditions that may exist. List the following paragraphs alarms that (as a minimum) monitor the system at the central control point, or that initiate shutdown of the appropriate advanced oxidation equipment components.

2.7.4.1 UV AOP System

Initiate system by interlocks if failure of major equipment components such as lamps, ballasts, or safety, followed by plant shutdown, if not acknowledged.

a. Provide UV system alarms and control interlocks for the following items:

    (1) Lamp failure

    (2) Ballast failure

    (3) Safety interlocks for open door on reactor vessel or panel

    (4) High water temperature in UV chamber

    (5) Low water flow to the UV chamber

    (6) Sleeve wiper failure

    (7) High pressure in UV chamber

(8) [_____].

b. Submit the following data for the AOP System

(1) Manufacturer's descriptive and technical literature; performance charts and curves, catalog cuts for specified equipment including: instrumentation and controls; capacities and pressure drop; model number; and installation instructions.

(2) Materials of construction; inlet and outlet pipe sizes; power demand requirements; and ozone generator cooling water flow rate.

(3) Spare parts data for each piece of equipment, current unit prices and source of supply.

(4) Manufacturer's descriptive and technical literature; performance charts and curves, catalog cuts for specified equipment including: instrumentation and controls; capacities and pressure drop; model number; and installation instructions.

(5) Materials of construction; inlet and outlet pipe sizes; power demand requirements; and ozone generator cooling water flow rate.

(6) Spare parts data for each piece of equipment, current unit prices and source of supply.

(7) Manufacturer's certificates stating that the equipment meets the specified requirements, and has been installed in accordance with the equipment manufacturer's requirements.

(8) Supply original equipment manufacturer (OEM) recommended preventative maintenance and recommended frequencies.

2.7.4.2 Metering Pump

Initiate system by pump failure, followed by plant shutdown, if not acknowledged. Provide metering pump alarms and control interlocks for the following items:

a. Hydrogen peroxide [sodium hypochlorite] feed

b. TiO2 feed

c. Pump failure

d. [_____].

2.7.4.3 Hydrogen Peroxide [Sodium Hypochlorite] [TiO2 Solution] Tank

Provide hydrogen peroxide [Sodium Hypochlorite] [TiO2 Solution] tank [alarms] [and control interlocks] with the following items:

a. High liquid level

b. Low liquid level

c. Low low liquid level

d. High temperature

e. High pressure

f. [_____].

2.7.4.4 Ozone System

Provide ozone system alarms and control interlocks with the following items:

a. High dew point in gas feed to ozone generator

b. Over current to the power supply unit (PSU)

c. Over voltage to the PSU, rectifier, and inverter

d. Over frequency protection

e. High temperature shut down

f. High inlet gas temperature

g. High inlet cooling water temperature

h. High gas pressure to the generator

i. Insufficient gas flow to the generator

j. High outlet ozone gas temperature

k. High moisture level in control cabinet

l. [_____].

Initiate system if major equipment component failure such as over current, over voltage, over frequency, high cooling water temperature or other condition that could damage the equipment or result in effluent non-compliance, followed by plant shutdown, if not acknowledged.

2.7.4.5 Gas Feed System

Provide gas feed system alarms and control interlocks with the following items:

a. High pressure across gas filters

b. High temperature in gas desiccant dryer

c. High pressure downstream of reducing valves

d. Air preparation system failure

e. Ozone monitor failure

f. [_____].

Initiate system if major equipment component failure, such as high cooling water temperature, air preparation failure, or other condition that could damage the air feed or ozone equipment, or result in effluent non-compliance, followed by plant shutdown, if not acknowledged.

2.7.4.6 Ozone Destruct System

Provide ozone destruct system alarms and control interlocks with the following items:

a. High ozone in ambient air space

b. High gas flow rate to destruct unit

c. Low temperature in ozone destruct unit

d. High ozone in destruct unit exhaust gas

e. Ozone destruct system failure

f. High ozone concentration in off gas

g. Destruct system failure

h. [_____].

Initiate ozone system alarm and shutdown if health and safety ambient ozone level non-compliance, followed by overall plant shutdown, if alarm is not acknowledged (high ambient ozone levels will not shutdown the ozone destruct system concurrently with other processes).

2.7.4.7 Cooling Water System

Provide cooling water system alarms and control interlocks with the following items:

a. Cooling systems failure

b. High water temperature

c. No/low cooling water flow

d. Pump failure

e. [_____].

Initiate ozone generator if major equipment component failure such as no/low cooling water flow, pump failure or other condition that could damage the gas feed, ozone equipment or result in effluent non-compliance, followed by plant system shutdown, if not acknowledged.

2.7.4.8 Metering Accuracy

Provide metering accuracy alarms and control interlocks with the following items: Ozone and Hydrogen Peroxide [Sodium Hypochlorite].

2.7.4.9 Ground Fault

Provide a ground fault protection alarm.

2.8 SPECIAL EQUIPMENT AND TOOLS

Provide one set of special tools, calibration devices, and instruments required for operation, calibration, and maintenance of the equipment. Provide a tube cleaning rack or racks with adequate capacity to hold [50] [100] percent of the dielectric tubes from the ozone generator being serviced. Equip each rack with locking casters to allow the rack easily removable between the ozone generator and the location where the dielectric tube cleaning occurs. Provide each dielectric with an individual padded holder.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before performing the work. Compare the limits of work for the equipment supplied to field conditions to ensure the limits previously identified for piping, electrical and control interfaces meet the actual physical requirements at the facility. Bring any discrepancies to the attention of the Contracting Officer for correction.

3.2 PREPARATION

****

NOTE: This paragraph covers actions required to physically prepare the surface, area, or site to incorporate the specified primary products.

****

Provide the UV system, reactor vessel, [ozone and feed gas equipment,] [hydrogen peroxide] [sodium hypochlorite] storage and feed system, [electrical support equipment,] and [_____] with an equipment pad isolated from the floor slab [as detailed on the drawings] [adequate to properly support the equipment]. Design and install reinforced concrete in accordance with Section 03 30 00 CAST-IN-PLACE CONCRETE. Prior to placing ozone piping, or other equipment, into service, clean it by one of the methods specified in CGA G-4.1. Passivate piping and equipment used to store or feed hydrogen peroxide in accordance with the hydrogen peroxide supplier's requirements.

3.3 EQUIPMENT INSTALLATION

Perform the equipment installation as indicated on the drawings, shop drawings, manufacturer's instructions and recommendations. Install piping, valves, fittings, and appurtenances in accordance with the manufacturers recommendations, as specified in Section 40 05 13 PIPELINES, LIQUID PROCESS PIPING, or as otherwise indicated. Give all valves, fittings, meters and other appurtenances unique identification numbers corresponding to those used in operation and maintenance manuals, and in AOP submittals prepared. Place identification numbers on brass identification tags and securely fasten all valves, fittings, meters and other appurtenances. Provide tags no less than 38 mm 1-1/2 inches in diameter with depressed black figures 13 mm 1/2 inch high. Provide PVDF, stainless steel, or PTFE piping for wet ozone service. Provide PVDF, stainless steel, or PTFE piping for dry ozone service. Provide copper or stainless steel oxygen piping. Provide stainless steel, PTFE or PVDF piping for hydrogen peroxide. [Insulate oxygen piping in accordance with

Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS].[Oxygen piping is not insulated.]

3.4 ELECTRICAL WORK

Perform electrical work in accordance with the drawings and applicable requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide equipment appropriate for continuous duty, and installation in a dusty, humid and corrosive environment. Comply with NFPA 70 for electrical equipment and wiring.

3.5 TOOLS

Provide tools to the Contracting Officer prior to the onsite training identified in paragraph FIELD TRAINING.

3.6 PAINTING/CORROSION PROTECTION

Coat and paint all ferrous surfaces. Indicate color as on the paint schedule or as otherwise approved. Touch up factory painted items as needed. Throughly clean factory painted items requiring touch up in the field for all foreign material, primed and top coated with the manufacturer's standard factory finish in accordance with the manufacturer's recommendations, including dry finish thickness. Paint equipment which did not receive a factory finish in accordance with the requirements indicated in Section 09 90 00 PAINTS AND COATINGS. Do not require painting corrosion resistant metals such as brass, bronze, aluminum, copper, galvanized steel and stainless steel unless otherwise specified.

3.7 CHEMICALS

****

NOTE: Coordinate these requirements with other specifications which may address extended operation and maintenance occurring in some HTRW Projects. If other supplies such as catalysts are required, include that information as well.

****

Provide the chemicals needed to do all the operational and start up testing, and completely refill the [oxygen], [hydrogen peroxide], [sodium hypochlorite], [_____] tanks at the time of contract completion.

3.8 WELDING

****

NOTE: Use second set of brackets when critical pipe welding is required.

****

Weld [piping in accordance with qualified procedures using performance qualified welders and welding operators. Quality procedures and welders in accordance with ASME BPVC SEC IX. Accept welding procedures qualified by others, and welders and welding operators qualified by another employer as permitted by ASME B31.1. Notify the Contracting Officer 24 hours in advance of tests. Weld structural in accordance with Section 05 05 23.16 STRUCTURAL WELDING.] [Specify welding and nondestructive testing procedures for piping in Section 40 05 13.96 WELDING PROCESS PIPING.]

3.9 MANUFACTURER'S SERVICES

****
NOTE: Use this paragraph when manufacturers are to provide: field quality control with onsite personnel for instruction/supervision of the installation or application of their products, for commissioning or startup, for demonstration or acceptance testing, and for operation assistance during the warranty period.

This paragraph covers requirements of the installer or manufacturer to demonstrate the operation and maintenance of equipment to the owner's personnel.
****

Provide a manufacturer qualified service representative, experienced in the installation, adjustment, operation and maintenance of the AOP system and equipment specified, for a minimum of [3] [_____] days to supervise the installation, adjustment, and commissioning and acceptance testing. If major components from multiple suppliers are provided, such as [UV system] [ozone generator] [air preparation system] [oxygen preparation system] [ozone destruct system] [_____], require each supplier to visit the site for a minimum of [3] [_____] days to provide these services. If the AOP system or any component needs corrective action prior to beginning of commissioning test, the manufacturer's representative coordinates with the Contractor to make all necessary modifications to meet these specified requirements. During [one] [_____] years operating period, require the major equipment suppliers onsite [2] [_____] times to verify that the equipment is operating properly and provide trouble shooting and technical assistance.

3.10 FIELD TESTS AND INSPECTIONS

****
NOTE: These tests are required for installed or completed work; they are different and separate from those required for materials and products prior to installation or application. Delete tests not applicable or required.

Provide in this section a reference to the plant commissioning or start-up specification which includes the processes in the treatment facility.
****

Factory test accessories such as the [UV equipment,] [AOP reactor vessel,] [ozone generator,] [ozone generator gas feed equipment,] and [_____] prior to shipment to the job site.

3.10.1 Leak Testing

Accomplish leak testing at the factory to verify the integrity of the [UV system] [reactor vessels] and associated gas and liquid piping. Accomplish the factory leak tests on the [UV system] [reactor vessel] and appurtenances following assembly at the factory. Include onsite hydrostatic leak testing for all piping between the upstream and downstream processes, and accomplished [per Section 40 05 13 PIPELINES, LIQUID PROCESS PIPING] [using potable water at a pressure 1.5 times the working pressure, or 350 kPa 50 psi] unless otherwise approved by the Contracting Officer. Isolate reactor vessel and appurtenances from the connecting piping and retested for leaks using potable water following assembly at the site. Test ozone generator gas connections with dry air or oxygen at the maximum pressure allowed by the manufacturer, or as identified above. Repair any gas or liquid leaks identified during the aforementioned testing and retest the system retested until the systems are free of leaks.

3.10.2 Commissioning Test

Submit Commissioning Test procedures by APO system manufacturers to the Contracting Officer for approval prior to the scheduling and performing the Commissioning Test. Submiot commissioning Test procedures for [UV system,] [AOP reactor vessel,] [ozone generator,] [ozone generator gas feed equipment,] and [_____]. Confirm the operability of the communications between AOP System control panels, including any programmable logic controllers (PLCs), and the plant control system. Test the AOP system to ensure the equipment and auxiliary components act as a complete and operational system. Include operation of all valves, pumps, compressors, analyzers, alarms, meters, interlocks, monitors, level and pump controls, sensors, switches, off gas destruct equipment and all other equipment associated with the AOP system.

3.10.3 Acceptance Test

Perform the Acceptance Test following the Commissioning Test. Do not allow Contractor to discharge effluent to the environment until the Acceptance Test has been successfully completed. Provide temporary tanks or similar means of temporary water storage by Contractor during Acceptance Test. Provide any temporary-use pumps, piping, hoses, valves, and fittings by Contractor as required to facilitate temporary water storage.

3.10.3.1 Acceptance Test Plan

Submit an Acceptance Test plan with testing procedure from manufacturer's of [UV system,] [AOP reactor vessel,] [ozone generator,] [ozone generator gas feed equipment,] and [_____] for approval to ensure the equipment meets the standards indicated. Coordinate this plan with other plans and unit operations to ensure they do not conflict and the AOP system is ready for testing. Include plans for temporary water handling during Acceptance Test. Coordinate and obtain regulatory approvals prior to notifying the Contracting Officer that the equipment is ready for testing.

Include a plan for a detailed description of proposed sampling and analysis required to document system performance. Include a plan detailing the sampling locations, frequency, analytical protocols, and duration which ensures the equipment to comply with the standards indicated. Submit the plan to the Contracting Officer [_____] [30] days prior to equipment start up. Coordinate work within this section with other sections to ensure upstream and downstream unit processes complete and operational prior to startup/commissioning the AOP unit.

Perform sampling, analysis, and sample turn around time to demonstrate system performance and effluent compliance. Sample the chemical parameters identified in paragraph PERFORMANCE REQUIREMENTS [and ambient and ozone off-gas destruction concentrations] [daily] [_____], monitor [at the locations identified on the drawings] [at the locations indicated in the startup/commissioning plan] for [7] [_____] days of continuous 24 hour operation, using analyses with detection limits one order of magnitude lower then the levels indicated in paragraph PERFORMANCE REQUIREMENTS.

3.10.3.2 Plan Calculations

Include the following calculations in the plan.

a. Headloss calculations through the process units at the design flow rate, including headloss calculations for associated [oxygen feed,] [compressed air,] and pumping systems.

b. Oxidant demand and subsequent AOP unit sizing.

c. Electrical usage rate.

d. Removal performance and material mass balance.

e. Chemical feed requirements and equipment sizing.

f. Diffuser system layout, mass transfer calculations.

3.10.3.3 UV System

a. During the acceptance test, Monitor the UV System continuously for [3] [_____] days by Contractor to demonstrate that the system meets the Performance Requirements specified herein.

b. Prior to the start of the acceptance test, propose the number, location of online UV lamps by the UV manufacturer based on the measured filtered UV transmittance and average lamp age. Deliver the average UV dose during the intensive tests as the specified minimum UV dose levels plus or minus 10 percent.

c. Give allowance to the loss in UV output through the clean quartz sleeves. Clean the lamps during testing at the frequency recommended by the UV manufacturer.

d. On each day of the acceptance test, collect and analyze grab samples for the influent and effluent of the UV System. Undertake the collection of and laboratory testing of all samples taken by the Contractor.

e. Hydraulic Tests: includes measuring hydraulic losses through each module and plotting on a curve showing flow rate on the horizontal axis and head loss in inches of water on the vertical axis.

f. Measure pressure at the upstream side of the trains and immediately downstream of the train.

g. Effluent Quality Tests: includes effluent quality tests to confirm that the effluent quality is satisfactory under the specified design conditions.

h. Supervise acceptance testing, and certify the system's performance by a qualified representative of the UV manufacturer during the tests.

i. If, in the opinion of the Contracting Officer, the acceptance test results does not meet the requirements specified herein, the UV manufacturer needs to fix/repair the unit to meet the specified performance requirements at no cost to the Government.

3.10.3.4 Ozone Generation System

****

NOTE: The installer or manufacturer should demonstrate the operation and efficiency of the equipment. Power consumption for ozone generation should be less than 10 kWhr per 0.5 kg pound of ozone generated assuming a PSA oxygen feed system is used to generate a 10 percent ozone feed; verify this with multiple equipment suppliers based on the specific ozone application pressures to be used, gas feed, and applied ozone concentration.

****

Test the ozone generation system to ensure that the actual ozone production, power usage, or water consumption rates meet recommended requirements. Measure power usage after achieving steady state conditions as determined by the ozone generator supplier. Measure power usage at the central motor control center or at each individual component including the [air dryer,] [refrigerant driers,] [desiccant driers,] [oxygen generator,] ozone generator, cooling water pumps, and master control panel. Assure power usage within [5] [_____] percent of [_____] kWh per kg pound of ozone generated at 100 percent of rated capacity. Also measure cooling water supply. Cooling water consumption rate are not to exceed [_____] L/s gpm at the parameters listed in paragraph OZONE GENERATOR SYSTEM by more than [5] [_____] percent. If the equipment does not meet the specified consumption rates, make the necessary system revisions to meet the rates specified at no additional cost to the Government. Also evaluate power usage at 25, 50, and 75 percent of the design production rate.

3.10.3.5 Diffuser or Injector System

Pressure test the entire gas piping system with dry air or oxygen at a minimum of [two] [_____] times the normal design pressure for a minimum of 60 minutes and such additional time as required for the Contractor to inspect the piping system for leaks. Repair all leaks and retest the system until no leakage is detected. Do not introduce ozone into the system until all leaks have been identified, repaired, and the system retested. Install [diffusers] [Injectors] in accordance with the suppliers recommendations. After installation, cover the [diffusers] [injectors] with clear water to a depth of approximately [1] [_____] m [3] [_____] feet. Release dry air or oxygen through the [diffusers] [injectors] and inspect the system for uniform air or oxygen distribution throughout the reactors. Following the initial testing at [1] [_____] m [3] [_____] feet, repeat the distribution testing at a water depth of [3] [_____] m [9] [_____] feet to ensure bubble distribution adequate throughout the reactor. Accomplish [diffuser] [Injector] replacement or repositioning as required to maintain uniform air distribution throughout the reactor. If after repositioning, air distribution throughout the reactor lacks uniformity, install additional redistributors or deflectors in the reactor as recommended by the [diffuser] [injector] supplier to accomplish uniform flow distribution throughout the reactor.

Accomplish all control testing prior to overall plant startup at no additional cost to the Government.

3.11 FIELD TRAINING

Provide a field training course for designated operating and maintenance staff members. Include training for operation of individual components as well as the integrated system, maintenance needs and procedures, instrument calibration, safety issues and emergency procedures, control and alarm features, troubleshooting equipment and control problems, and laboratory analytical procedures. Provide training during normal working time and start after the system is functionally complete but prior to performance testing. Cover all of the items contained in the operating and maintenance manuals during field training. Require each major equipment vendor including, but not limited to, the UV system, the ozone generator, ozone destruct system, ozone monitoring system, and gas feed system to provide two [8] [_____] hour periods of classroom and hands-on operating instruction to the individuals selected by the Contracting Officer. The first period will be at system startup and the second [as defined by the Contracting Officer] [at the end of the Contractor's operating contract, prior to turning over to the long term facility operator]. Upon completion, submit certificates indicating the designated personnel have received training specified and have successfully operated the installed AOP equipment.

3.12 POSTING FRAMED INSTRUCTIONS

Post framed instructions containing wiring and control diagrams, under glass or in laminated plastic, adjacent to the equipment or where otherwise directed before acceptance testing of the system. Frame condensed operating instructions, prepared in typed form, as specified above and posted beside the diagrams. Post the framed instructions before acceptance testing of the systems.

3.13 MAINTENANCE

3.13.1 Extra Materials

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NOTE: Delete inapplicable portions of these paragraphs. Coordinate this section with other sections of the specifications to ensure there are not conflicts regarding supplying consumables. Verify the duration of the initial operating period, which is generally 1 year.

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Furnish the initial supplies to fill the vessels, as well as all consumables during the startup, prove out, and initial operation period. At the time the Contractor turns the plant over to the long term Operation and Maintenance Contractor, refill the vessels storing consumables such as [LOX,] [hydrogen peroxide,] [sodium hypochlorite,] [and] [_____] within [two] [five] days prior to the plant turn over.

3.13.1.1 Lamps

Provide a complete set of lamps reserved for change out by the equipment supplier following the one year warranty period. Deliver extra set of lamps to the treatment facility 60 days prior to the end of the one year warranty period and install by the Contractor. Provide lamp replacement during the one year warranty period by the supplier, as needed by the

Contractor.

3.13.1.2   Spare Parts

Provude, in addition to the lamps specified above by the supplier, a minimum of ten percent of each of the following items, or a minimum of two, whichever is greater:

a. Lamp ballasts

b. Quartz sleeves

c. End seals

d. Socket connectors

e. O-rings

f. Quartz sleeve cleaners

g. Diffusers

h. Rotometers

i. Generator dielectrics

j. Generator dielectric fuses

k. pH probe element

l. ORP probe element

3.13.2   Maintenance Service

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NOTE: Delete this paragraph if UV lamps are not used. Low pressure lamps have an approximate life of 7000 to 10000 hours.

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Changing out lamps, ballasts, and quartz tube wipers, at the frequency recommended by the manufacturer during the one year warranty period or as otherwise required, is Contractor's responsibility. Provide lamps and ballasts supplied as specified below in addition to the complete set supplied for installation (following the warranty period) and install those as needed during the warranty period. Clean ozone generator dielectrics in accordance with the manufacturer's recommendations immediately prior to the conclusion of the Contractor's operating period; or after one year, if greater than one year after startup, and at the conclusion of the Contractor's operating period.

3.13.3   Operating Instructions

Submit [six] [_____] complete copies of operating instructions outlining the step-by-step procedures required for system start-up, operation and shutdown, routine maintenance, potential breakdowns and repairs, and troubleshooting. Include the instructions with drawings and schematics of the system as installed. Include instructions with the manufacturer's name, model number, service manual parts list and brief description of all equipment and their basic operating features. Include instructions with, but not be limited to, the following:

a. System layout showing piping, valves and controls, process flow diagrams, piping and instrumentation diagrams with all valves, meters, and similar units identified.

b. Approved wiring and control diagrams prepared in accordance with ANSI/ISA 5.1 including a drawing index, legend and symbols list, and abbreviations and identifiers.

c. A control sequence and control narrative describing startup, how to make adjustments to the equipment during operation, standard and emergency shutdown procedures.

d. Operating and maintenance instructions for each piece of equipment, including lubrication instructions and other periodic maintenance and inspection information as well as trouble shooting guides.

e. Manufacturer's bulletins, cut sheets and descriptive data, parts lists, and recommended spare parts, and sources of supply for all major pieces of equipment.

-- End of Section --