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USACE / NAVFAC / AFCEC **UFGS-46 30 13 (February 2011)**

Preparing Activity: USACE **Superseding**
UFGS-44 44 53 (October 2007)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2025
****

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DIVISION 46 - WATER AND WASTEWATER EQUIPMENT

SECTION 46 30 13

ADVANCED OXIDATION PROCESSES (AOP)

02/11

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USACE / NAVFAC / AFCEC **UFGS-46 30 13 (February 2011)**

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SECTION 46 30 13

ADVANCED OXIDATION PROCESSES (AOP)
02/11

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NOTE: This guide specification covers the requirements for liquid phase advanced oxidation processes using titanium dioxide or hydrogen peroxide and/or ozone with or without ultraviolet light.

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)**.**
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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.
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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 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 B16.18	(2021) Cast Copper Alloy Solder Joint Pressure Fittings
ASME B16.22	(2021) Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B31.1	(2024) Power Piping
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	(2019) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1

AMERICAN WELDING SOCIETY (AWS)

AWS B2.1/B2.1M	(2021) Specification for Welding Procedure and Performance Qualification
AWS D1.1/D1.1M	(2020; Errata 1 2021) 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 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 A269/A269M	(2024) Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A276/A276M	(2024) 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 A403/A403M	(2022b) Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
ASTM A774/A774M	(2024) 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 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	(2014) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B209M	(2014) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate (Metric)
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 D3222	(2018a) Standard Specification for Unmodified Poly(Vinylidene Fluoride)

	(PVDF) Molding Extrusion and Coating Materials
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

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)

NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
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) National Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-301-01	(2023; with Change 2, 2024) Structural 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

AOP System; G, [_____]

Air Preparation System; G, [_____]

Oxygen Generation System; G, [_____]

LOX Storage System; G, [_____]

Ozone Generation System; G, [_____]

Reactor Vessel; 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

AOP System; G, [_____]

Calculations; G, [_____]

Commissioning/Demonstration Plan; G, [_____]

Manufactured Units

Performance Requirements; G, [_____]

Qualifications; G, [_____]

SD-06 Test Reports

Performance Requirements; G, [_____]

SD-07 Certificates

AOP System

Field Training

SD-10 Operation and Maintenance Data

AOP System; G, [_____]

Maintenance; 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 waste water 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

Equipment provided must duplicate equipment that has been in satisfactory service for a minimum of [2] [_____] years prior to bid opening. The UV oxidation system supplier isresponsible 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 subcontractor's 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 as indicated in ETL 1110-1-161 ULTRAVIOLET/CHEMICAL OXIDATION dated 29 March 96.

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.

****

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] [_____]
Maximum AOP reactor operating pressure	[_____] kPa psi
Reactor inlet pipe diam.	[_____] mm inch
Reactor outlet pipe diam.	[_____] mm inch
Max. cooling water temp.	[_____] degrees C F
Max. cooling water flow rate	[_____] L/s gpm
Max. AOP influent flow rate	[_____] L/s gpm

Minimum reactor vessel detention time	[_____] minutes
Max. liquid temperature rise across AOP reactor	[_____] degrees C F

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. Test report must indicate the recommended position of the controls.

a. Influent characteristics:

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

Organic Constituent Concentration	
[_____]	[_____] µg/L
pH	[_____] units
Total Organic Carbon (TOC)	[_____] mg/L

b. Effluent requirements:

Organic Constituent Concentration	
[_____]	[_____] g/L
Total Organic Carbon (TOC)	[_____] mg/L
pH	[_____] units
Maximum effluent temperature	[_____] degrees C F

c. Efficiency factors:

Ozone usage	[_____] mg/L
Hydrogen peroxone usage	[_____] mg/L
Power consumption	[_____] kW/L
[Catalyst 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 previous treatability studies should be properly documented to include the information contained in ETL 1110-1-161.

****

The previously conducted treatability study information contained in Appendix [_____] is provided for the Contractor's information. The study results indicate [ultraviolet oxidation] [peroxone] [_____] 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. Equipment is to be supported 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. Nameplates are to be provided 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; stainless steel must conform with ASTM A276/A276M, type 316.

2.4.2   Pipe and Fittings

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

Gasket materials for pipe and fittings are to be silicon, or teflon 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, Type 316L with maximum carbon content of 0.04 percent. Conform flanged fittings sto ASME B16.5, F316L Class 150 with 2 mm 1/16 inch minimum thickness silicon, teflon, expanded PTFE, PVDF, or viton gaskets. Butt weld fittings must conform to ASTM A403/A403M and MSS SP-43, Grade 316L, Schedule 10S with full penetration welds.

b. Pipe less than 100 mm 4 inch will be type 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 are to be in accordance with ASME B16.5 with 2 mm 1/16 inch minimum thickness silicone, teflon, expanded PTFE, PVDF, or viton gaskets. Butt weld fittings must 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, Type TP316. Wall thickness are to be adequate for the pressure required. Fittings must be compression type made from bar stock material conforming to ASTM A276/A276M, Type 316, with forgings conforming with ASTM A182/A182M, Type 316. 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. Pipe and joints are to be rated for a working pressure of [_____] kPa psi. Solvent cement joints must conform to the requirements of ASTM D2564. Flanged joint diameter and drilling must 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. Pipe, tubing and associated fittings are to be rated for a minimum working pressure of [_____] kPa psi.

2.4.2.4   Polyvinylidene Fluoride (PVDF) Pipe and Tubing

PVDF pipe, tubing and fittings are to be manufactured from materials conforming to ASTM D3222 for type II homopolymers. Pipe tolerances for outside diameter and wall thickness will be in accordance with ASTM D1785 for schedule 80 pipe. Tubing and associated fittings are to be rated for a minimum working pressure of [_____] kPa psi.

2.4.2.5   Copper Pipe

Pipe 100 mm 4 inch and smaller will be standard weight, seamless, cold drawn type conforming to ASTM B88M ASTM B88 Type K, temper H. Fittings are to be cast or wrought copper alloy, solder joint type, conforming with ASME B16.18 or ASME B16.22, as appropriate. Solder used will be lead free 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

Pipe hangers and supports will conform to MSS SP-58.

2.4.4   Stainless Steel Gas Tubing and Fittings

Stainless steel tubing will conform to ASTM A778/A778M. Wall thicknesses will be a minimum of 1.5 mm 0.062 inch for tubing 250 mm 10 inches and smaller, tubing 300 mm 12 inch in diameter will have a minimum wall thickness of 1.9 mm 0.078 inch, tubing 350 through 450 mm 14 through 18 inch in diameter will have a minimum wall thickness of 2.7 mm 0.109 inch. Fittings will conform to ASTM A774/A774M, and be of the same material, grade, schedule or wall thickness as specified for tubing. Joints are to be 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

2.4.5.1   Liquid Oxygen (LOX)

LOX valves are to be bronze or Type 316 stainless steel intended for cryogenic extended service. Materials must be compatible with the piping installed.

2.4.5.2   Gate

Gate valves are to comply with the requirements of Section 22 00 00 PLUMBING, GENERAL PURPOSE.

2.4.5.3   Ball

Ball valves are to comply with the requirements of Section 22 00 00 PLUMBING, GENERAL PURPOSE. Valves used for hydrogen peroxide service are to be passivated and vented in accordance with the hydrogen peroxide supplier recommendations.

2.4.5.4   Check

Check valves are to comply with the requirements of Section 22 00 00 PLUMBING, GENERAL PURPOSE.

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 316L 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. Injectors are to be designed 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 AOP Reactor Vessel.

****

Fine bubble diffusers are to be ceramic construction, of the tube, disc or dome type. Ceramic are to be of bonded silica or alumina, and be resistant to degradation by ozone in oxygen concentrations of [16] [_____] percent. Pore size will be a maximum of [50] [_____] um [0.002] [_____] inch or the manufacturer's standard pore size which will produce bubbles [2] [_____] mm [0.005] [_____] inch in diameter or smaller. Gas flow per diffuser will be a maximum of standard [_____] L/s cubic feet/minute at a submergence of [_____] m feet. Maximum allowable headloss per diffuser islimited to [_____] mm inch. Brackets, holders, bolts, rods, washers and other accessories are to be 316 stainless steel unless otherwise indicated. Gaskets are to be of silicone construction.

2.4.8   Couplings

Fittings, flanges, bolts, nuts and washers are to be the same material as the piping unless otherwise indicated. Sleeve type couplings for ozone service are to be of stainless steel conforming with ASTM A312/A312M, Grade TP316L with ozone resistant gaskets. Couplings for non-ozone ferrous metal piping will be ASTM A53/A53M, Grade B.

2.4.9   Insulating Joints

Insulating joints are to be provided when ferrous metal piping is joined with non-ferrous metal piping, fitting or valve materials. Insulating flanges are to be installed and have insulating flange gaskets, insulating sleeves for studs, and insulating washers for both sides of flanges. Steel washers are to be installed between the insulating washers and nuts. Couplings are to be of 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 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.

****

In pipeline static mixers are to be installed [at the locations indicated] [upstream of the reaction chamber]. Mixers are to be [installed in a flanged section of piping] [with removable mixing sections] [inserted 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. Mixers [and housing] are to be constructed of [Grade 316 stainless steel] [_____] and be compatible with [hydrogen peroxide] [_____]. [The static mixer must be ported 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: 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 are to be applied 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. The name used for the manufactured unit must be consistent throughout the specification.

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.

Additional information is contained in ETL 1110-1-161.

****

Submit wiring and control diagrams, systems layouts and isometrics, component identification tables, instructions, and other sheets, prior to posting. 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 are to be prepared in typed form, framed and posted beside the diagrams.

2.5.1 Swing Adsorption Oxygen Generation System

The Oxygen Generation System are to be Swing Adsorption type. [Pressure swing adsorption (PSA)] [Vacuum swing adsorption (VSA)] system equipment must be 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. [PSA] [VSA] system equipment must include all work from the outside air inlet to the ozone generator inlet connection. The [PSA] [VSA] system must be 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.

2.5.2 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. 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 MECHANICAL SYSTEMS, properly edited, must be enclosed in the contract documents.

****

LOX storage system and associated equipment must comply with NFPA 55 and CGA G-4.4. Tanks, vaporizers and regulators are to be suitable for exterior installations. Cleaning for components, equipment, valves, piping and tanks for oxygen service are to be accomplished in accordance with CGA G-4.1, CGA HB. The system must be rated 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. System must be supported and braced 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 MECHANICAL SYSTEMS] [as indicated].

2.5.2.1 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.

****

Bulk LOX storage tanks are to be [_____] kg pound double walled vertical 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 [Grade 304 stainless steel] [9 percent nickel steel] [_____], the outer shell constructed of carbon steel with a minimum outer shell thickness of [10] [_____] mm [0.375] [_____] inch. Annular area between the inner and outer walls are to be insulated to limit oxygen boil off rate to less than [0.25] [_____] percent of the tank capacity per day at the maximum ambient conditions. Piping must be copper or 316 stainless steel. Fittings must be bronze or 316 stainless steel.

2.5.2.2 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).

****

Vaporization equipment will consist of a minimum of [2] [3] ambient air vaporizers and [single] [double] regulator system complete with automatic switching and a manual bypass. Each vaporizer must be rated 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. The vaporizer extrusions must have extra wide spacings between the individual extrusions with a minimum area per extrusion of [1.65] [_____] square meters/meter [5] [_____] sf/ft. [Heaters are to be provided 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 are capable of warming the oxygen feed gas to a temperature range between [10 and 22] [_____] degrees C [50 and 72] [_____] degrees F]. Each vaporizer must operate 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.

Piping between the LOX tank and ozone generator are to be insulated as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.5.2.3 Regulators

Regulators are to be factory tested 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. Regulators are to be rated at 1030 kPa 150 psi, and constructed of 316 stainless steel.

2.5.3 Ozone Generator Air Feed System

System equipment which processes ambient air directly as the ozone generator feed gas must be provided 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. [The equipment must be skid mounted.] Adsorption vessels are to be designed and constructed in accordance with ASME BPVC SEC VIII D1. Adsorption material must be [activated alumina] [_____]. The unit is to be completely wired requiring only an external connection for a single external power supply and remote monitoring [and control]. The air preparation system supplier isresponsible for all work from the outside air inlet to the ozone generator inlet connection. The air preparation system is to be a continuous output 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

2.5.4 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.

****

Ozone generation equipment are to be continuous duty water cooled, multi-tube glass or non-glass multitube dielectric [horizontal tube] [vertical tube] assemblies contained in a pressure vessel [with hinged gas-tight doors] with a rated design pressure of [_____] kPa psi. Each unit is to be provided with [medium] [high] frequency electrical power supply units including input and output transformers, power controller, frequency inverter, harmonic mitigation equipment (if required). The generator must be provided 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]. All equipment, valves, piping, associated appurtenances must be 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

2.5.4.1 Ozone Generator Vessels

All ozone generator metal parts which come into contact with ozone or cooling water are to be constructed of Type 316L stainless steel. The vessel must be designed 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. The vessels are to be constructed in accordance with ASME BPVC SEC VIII D1 code. Provide viewing ports to allow visual inspection of all internal dielectrics during operation.

2.5.4.2   Dielectric Tubes

Dielectric tubes are to be constructed to resist thermal shock and to evenly distribute the applied electrical charge over the entire dielectric surface without arcing. Dielectric tubes are to be formed 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. Dielectric tubes are to be protected 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   Ozone Destruct System

****

NOTE: High concentrations of chlorinated organics may be liberated by systems which 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.

****

Ozone off gas destruction equipment must be thermal assisted catalyst destruct type units suitable for moist ozone in [oxygen] [air] service. The catalyst containment unit, piping, ductwork, and other metallic components are to be constructed of 316 stainless steel. The units are to be capable of destroying contactor off gas generated by the ozone generators which feed the AOP reactors. The ozone destruction unit must have the capability to function at a minimum turn down ratio of 20 to 1. Each off gas destruction unit are to be a skid mounted unit consisting of [a demister,] an electric resistance heater, catalyst trays and containment vessel [, and a centrifugal blower]. The destruction unit discharge duct must be sloped away from the destruct unit to reduce the probability of catalyst fouling from condensation. Ducts carrying ozone laden off gas from the AOP reactors are to be sloped to a low point valved drain located upstream of the ozone destruct system. The ozone destruct system must reduce the ozone concentration 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. Normal operation is defined as [50] [_____] percent of the maximum off gas flow rate with an ozone concentration of [1.0] [_____] percent by weight. Ozone destruction equipment are 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

The catalyst are to be non-hazardous [manganese dioxide/copper oxide] [nickel] [_____] based material suitable for catalytic ozone destruction at the specified conditions. Provide the catalyst containment unit swith 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.

2.5.6 Hydrogen Peroxide 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. Process safety management requirements must be followed 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.

****

The hydrogen peroxide storage tank must be constructed of cross linked polyethylene, 316 stainless steel, or 99.5 percent pure aluminum alloys designated in [ASTM B209M] [ASTM B209] as 1060, 5254, 5652. Hydrogen peroxide storage tanks are to be provided with secondary containment [as detailed on the drawings] [_____] with a minimum capacity equal to [110] [_____] percent of the maximum storage tank volume. Hydrogen peroxide storage tanks are to be equipped 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. All piping connections must be flanged. Conform feed pumps to the requirements of Section 46 30 00

WATER AND WASTEWATER CHEMICAL FEED SYSTEMS.

2.5.7 Redox Potential Meter

Provide the oxidation reduction meter [where indicated on the drawings] [on the effluent line of each reactor]. Probe is to be easily removable without interrupting service. Probe materials are to be 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. Probe must transmit output to an ORP analyzer with digital output. The ORP analyzer must transmit a [[4 to 20] [_____] mA signal proportional to the ORP] [direct digital reading] to the central control unit.

2.5.8 pH Probe

The pH probe is to be provided [where indicated on the drawings] [on the effluent line of each reactor]. Ensure probe is easily removable without interrupting service. Probe materials are to be resistant to ozone as well hydrogen peroxide 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. Probe must transmit output to a pH analyzer with digital output. The pH analyzer must transmit a [[4 to 20] [_____] mA signal proportional to the pH] [direct digital reading] to the central control unit.

2.5.9 Ozone Monitors

2.5.9.1 Vapor Phase

Separate ozone monitors are to be provided 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]. The ambient air monitoring unit intake is tobe located [within 455 mm 18 inches above the treatment plant floor] [at the location shown on the drawings] [adjacent to the AOP process equipment]. The ambient air monitors are to be interlocked with the ozone generation system to initiate an alarm condition, and ozone generator shut down when readings exceed preset levels. Analyzers are to be [4 to 20 mA] [direct digital] output ultraviolet adsorption photometer type with built in pressure and temperature compensation. Ozone off gas monitor must have a minimum of five separate ranges to monitor concentrations between [[0 to 15] [_____] percent,] [[0 to 99,000] [_____] ppm by volume]. Ambient air and off gas destruct monitors must have a minimum of five separate ranges to monitor concentrations between [0 to 10] [_____] ppm. Each monitor is to be provided with a builtin digital ozone concentration readout at the unit.

2.5.9.2 Liquid Phase

Liquid phase monitors are to be provided [where indicated on the drawings] [on the effluent line of the last reactor]. Sensor must transmit output to an ozone analyzer with digital display and remote signal transmission to the central control unit. Probe must transmit output to a liquid phase ozone analyzer with digital output. The liquid phase ozone analyzer must transmit a [[4 to 20] [_____] mA signal proportional to the ozone concentration] [direct digital reading] to the central control unit.

2.5.10 Temperature Sensors

Temperature sensors are to be dual switch trip point independently adjustable type with a minimum accuracy of 0.5 percent of full scale. Thermal system is to be constructed of 316L stainless steel. Temperature range will be from [0 to 100] [_____] degrees C [32 to 212] [_____] degrees F and suitable for the medium monitored. Sensor must transmit output to an analyzer with digital output. The analyzer must transmit a [[4 to 20] [_____] mA signal proportional to the temperature] [direct digital reading] to the central control unit.

2.5.11 Compressors

Air compressors are to conform to CAGI B19.1. Air compressors are to be factory packaged [rotary screw] [centrifugal] [rotary] [reciprocating] type units. The air compressors are to be packaged in an enclosure with sound attenuating properties which allow a maximum noise level measurement of 75 dBA at the equipment enclosure. Air compressors are to be [water] [air] cooled and rated for continuous operation. Guards must shield exposed moving parts. Compressor motors and starters are to conform with the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Air compressors are to have the manufacturer's name and address, together with trade name, and catalog number on a nameplate securely attached to the equipment. Any special maintenance instructions (required before startup or shutdown) are to be included in the Operations and Maintenance Manuals. Compressor equipment used for processing ambient air for the ozone generator feed gas are to include 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. Compressor receivers, air piping, valves and appurtenances unless otherwise specified, are to be in conformance with Section 22 00 00 PLUMBING, GENERAL PURPOSE. Dry contacts and 4 to 20 mA signals are to be provided 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

2.5.12 Blowers

Blowers are to conform to [Section 43 11 00.10 OFF-GAS FANS, BLOWERS AND PUMPS] [_____]. Dry contacts and 4 to 20 mA signals are to be provided in the control panel for remote monitoring.

2.5.13 Dew Point Monitor

The dew point transmitter are to be of a solid state design housed in a NEMA 4 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. The transmitter must receive the signal 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. Sensor must transmit output to an analyzer with digital display.

2.5.14 Pressure Gauges

Water pressure gauges are to be glycerine filled units conforming to the requirements of ASME B40.100.

2.5.15 Sampling Ports

Aqueous and gas phase sampling ports are to be provided [where indicated on the drawings] [upstream and downstream of each reactor vessel]. Sampling ports are to be provided at locations accessible to plant operators. Ports and associated piping are to be constructed of [6] [12] [_____] mm [1/4] [1/2] [_____] inch minimum diameter [PVDF] [316 stainless steel] [teflon] [_____] with [PVDF] [316 stainless steel] [_____] [NPT x hose] ball valves.

2.5.16 Gas Flow Meters

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

Flow meters for ozone or oxygen applications must have stainless steel body, tube, valves, floats, and knobs with glass windows. Flow meter must be rated 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. The [air] [oxygen] feed stream to the ozone generator must also be equipped with a flow meter. Each flow meter must have an easily readable scale in cms scfm 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. Sensor must transmit output to an analyzer with digital display.

2.5.17 Level Monitoring

Pressure type level sensors, associated analyzers and transmitters are to be provided for each liquid process tank associated with the AOP system. Ensure sensor element is removable for servicing or replacement without taking the tank out of service. As a minimum, the following tanks are to be equipped with level monitoring equipment: [reactor vessels,] [hydrogen peroxide storage and feed tanks,] [equalization tank,] [effluent storage and equalization tanks,] [_____]. Each level control element are to be of solid state design 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.

2.5.18 Reactor Vessel

****

NOTE: Coordinate paragraph Gas Flow Meters requirements for the application; 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 peroxone 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.

****

The reactor vessel will be [circular] [rectangular], fabricated of [316L stainless steel] [concrete conforming to Section [03 30 00 CAST-IN-PLACE CONCRETE] [_____] provided with [_____] mm inch, [_____] kPa psi flanged connections.] Reactor vessels will have a minimum water depth above the diffusers of [6] [_____] m [18] [_____] feet, with a minimum free board water depth above the liquid level of 600 mm 2 feet. [Reactor will be designed to accommodate a vacuum of [25] [_____] mm [1] [_____] inch applied to the reactor headspace.] Welding will be performed 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. Reactors are to be equipped 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, [quartz sheath wipers], [UV lamps], [pH probe], [redox meter], [level switch], site glass liquid level indicator, and other connections as indicated or required. Reactor vessels are to be equipped 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. The viewing port must be covered with clear plastic material not susceptible to ozone degradation, with a minimum thickness of [10] [_____] mm [3/8] [_____] inch.

2.6 ELECTRICAL

Electrical products are to be in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Reactor vessels containing ultraviolet lamps are to be independently grounded.

2.6.1 Motors

Motors, all motor starters, and any control or signal wiring required for the operation of the specified equipment are to be provided and installed 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

Manual or automatic controls, protective or signal devices required for the operation specified, and any control wiring required for controls and devices, provided. Enclosures for local power and control panels are to conform to NEMA ICS 6.

2.6.3 Ultraviolet Equipment Electrical Requirements

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

b. Ground fault detection or independent ground will be standard with the UV lamp equipment.

c. Control and monitoring components are to be housed in NEMA enclosures. Internal components are to be sealed from the environment. System electronics to be used in an interior environment are to be housed in enclosures conforming to NEMA 250 TYPE 12. System electronics to be used in an exterior and corrosive environment, as defined in NEMA 250, are to be housed in enclosures conforming to NEMA 250 TYPE 4X.

d. Provide sufficient cooling to the medium and high temperature UV bulbs as well as associated ballasts to prevent overheating.

e. Wiring and electrical connections are to be protected against moisture and corrosive gases to prevent electrical shorts or failure. Electrical installation and materials are to conform to NFPA 70. The unit must be completely wired requiring only an external connection for a single external power supply and remote monitoring and control.

f. Interconnecting, multiconductor, unshielded cables must be suitable for outdoor installation. Insulation will be thermoplastic rubber with an operating range of minus 60 to 125 degrees C minus 75 to 260 degrees F with low temperature flexibility and flame retardants. UV stabilized jacketing must be resistant to oils, chemicals, fuels, solvents, and to mechanical abuse and abrasion. Cable must be supplied by the equipment manufacturer and be of sufficient length and number for a complete system.

g. Cableways provided are to be stainless steel, 1.98 or 1.59 mm 14 or 16 gauge thick.

2.7 AOP CONTROL SYSTEM

****

NOTE: Delete items within this paragraph that do not apply. Not all UV systems (especially those with low intensity lamps) have light intensity monitors; verify design requirements for type or need of lamps. Hydrogen peroxide monitoring on all but very large plants (larger than5.7 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 the controls and instrumentation section of the specification; or if none is included and an autodialer is required, include those requirements in this paragraph.
****

Equipment will be locally controlled and 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]. Instruments are to be provided with mounting hardware as appropriate. Transmitters with digital outputs must be accurate to within [_____] percent. All equipment will be designed for operation on a 120 volts 60 hertz electrical input. Provide controls to remotely monitor [and adjust] [hydrogen peroxide 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

The ozonation control system must be interfaced with the plant central control system. Changes to the ozone generator equipment operating conditions are to be accomplished locally or from the master control panel. The power, control and instrumentation system provided 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. An emergency stop button must be provided at the local generator control panel. The ozone generator must be protected 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 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. The following paragraphs list alarms that (as a minimum) are to be monitored at the central control point, or that will initiate shutdown of the appropriate advanced oxidation equipment components.

2.7.3.1 AOP System

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

a. AOP system alarms and control interlocks are to be provided 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 AOP reactor vessel
    (5) Low water flow to the reactor vessel
    (6) Sleeve wiper failure
    (7) High pressure in reactor vessel headspace
    (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.

2.7.3.2 Metering Pump

Pump failure must initiate system, followed by plant shutdown, if not acknowledged. Metering Pump alarms and control interlocks are to be provided for the following items:

a. Hydrogen peroxide feed
b. Catalyst feed
c. Pump failure
d. [_____].

2.7.3.3 Hydrogen Peroxide Tank

Hydrogen peroxide tank [alarms] [and control interlocks] are to be provided for the following items:

a. High liquid level
b. Low liquid level
c. Low low liquid level
d. High temperature
e. High pressure
f. [_____].

2.7.3.4 Ozone System

Ozone system alarms and control interlocks are to be provided for 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. [_____].

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 must initiate system, followed by plant shutdown, if not acknowledged.

2.7.3.5 Gas Feed System

Gas feed system alarms and control interlocks are to be provided for 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. [_____].

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 must initiate system, followed by plant shutdown, if not acknowledged.

2.7.3.6 Ozone Destruct System

Ozone destruct system alarms and control interlocks are to be provided for 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. [_____].

Health and safety ambient ozone level non-compliance must initiate ozone system alarm and shutdown, 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).

2.7.3.7 Cooling Water System

Cooling water system alarms and control interlocks are to be provided for the following items:

a. Cooling systems failure
b. High water temperature
c. No/low cooling water flow
d. Pump failure
e. [_____].

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 must initiate ozone generator, followed by plant system shutdown, if not acknowledged.

2.7.3.8 Metering Accuracy

Metering accuracy alarms and control interlocks are to be provided for the following items: Ozone and Hydrogen Peroxide

2.7.3.9 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 to be easily moved between the ozone generator and the location where the dielectric tube cleaning will occur. Each dielectric is to be provided 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 reactor vessel, [ozone and feed gas equipment,] [hydrogen peroxide 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]. Reinforced concrete are to be designed and installed in accordance with Section 03 30 00 CAST-IN-PLACE CONCRETE. Prior to placing ozone piping, or other equipment, into service it is to be cleaned by one of the methods specified in CGA G-4.1. Piping and equipment used to store or feed hydrogen peroxide must be passivated 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. Piping, valves, fittings, and appurtenances are to be installed in accordance with the manufacturers recommendations, as specified in Section 22 00 00 PLUMBING, GENERAL PURPOSE, or as otherwise indicated. All valves, fittings, meters and other appurtenances are to be given unique identification numbers corresponding to those used in operation and maintenance manuals, and in AOP submittals prepared. Identification numbers are to be placed on brass identification tags and securely fastened to all valves, fittings, meters and other appurtenances. Tags are to be no less than 38 mm 1-1/2 inches in diameter with depressed black figures 13 mm 1/2 inch high. Piping for wet ozone service must be PVDF, stainless steel, or PTFE. Piping for dry ozone service must be PVDF, stainless steel, or PTFE. Oxygen Piping will be copper or stainless steel. Hydrogen peroxide piping is to be stainless steel, PTFE or PVDF.

Oxygen piping will [be insulated in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS] [not be insulated].

3.4 ELECTRICAL WORK

Perform electrical work in accordance with the drawings and applicable requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Equipment is to be appropriate for continuous duty, and installation in a dusty, humid and corrosive environment. Electrical equipment and wiring must comply with NFPA 70.

3.5 TOOLS

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

3.6 PAINTING/CORROSION PROTECTION

All ferrous surfaces are to be coated or painted. Color will be as indicated on the paint schedule or as otherwise approved. Factory painted items are to be touched up as needed. Factory painted items requiring touch up in the field are to be thoroughly cleaned of 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. Equipment which did not receive a factory finish must be painted in accordance with the requirements indicated in Section 09 90 00PAINTS AND COATINGS. Painting corrosion resistant metals such as brass, bronze, aluminum, copper, galvanized steel and stainless steel is not required 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], [catalyst], [_____] tanks at the time of contract completion.

3.8 WELDING

****

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

****

[Piping will be welded in accordance with qualified procedures using performance qualified welders and welding operators. Procedures and welders are to be qualified in accordance with ASME BPVC SEC IX. Welding procedures qualified by others, and welders and welding operators qualified by another employer may be accepted as permitted by ASME B31.1. Notify the Contracting Officer 24 hours in advance of tests. Structural members are to be welded in accordance with Section 05 05 23.16 STRUCTURAL WELDING.] [Welding and nondestructive testing procedures for piping will be as specified in Section 40 05 13.96 WELDING PROCESS PIPING.]

3.9 SAMPLING AND ANALYSIS

Perform sampling, analysis, and sample turn around time to demonstrate system performance and effluent compliance. Submit a commissioning/demonstration plan 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. Coordinate and obtain regulatory approvals prior to notifying the contracting officer that the equipment is ready for testing.

3.9.1 Plan Details

The plan will include a detailed description of proposed sampling and analysis required to document system performance. A plan detailing the sampling locations, frequency, analytical protocols, and duration which will ensure the equipment complies 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 are complete and operational prior to startup/commissioning the AOP unit.

3.9.2 Plan Calculations

Include the following calculations in the commissioning/demonstration plan.

a. Headloss calculations through the process units at the design flow rate, including headloss calculations for associated 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.

3.9.3 Chemical Sampling

The chemical parameters identified in paragraph PERFORMANCE REQUIREMENTS [and ambient and ozone off-gas destruction concentrations] are to be sampled [daily] [_____], monitored [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 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. Condensed operating instructions, prepared in typed form, are to be framed as specified above and posted beside the diagrams. Post the framed instructions before acceptance testing of the systems.

3.11 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.
****

Accessories such as the [UV equipment,] [ozone generator,] [compressor,] [ozone generator gas feed equipment,] and [_____] are to be factory tested prior to shipment to the job site.

3.11.1 AOP Reactor Vessel

The AOP reactor vessel and attached appurtenances are to be assembled at the factory and an operational test of all components accomplished prior to shipment. Certification that the equipment and components assembled at the factory are operational and meet the specification requirements are to be provided to the Contracting Officer a minimum of [10] [_____] calendar days prior to shipment. Components not assembled at the factory aresubject to the same tests and inspections prior to onsite leak testing using potable water. Following installation at the project site, and prior to leak testing, retest the AOP system to ensure the equipment and auxiliary components act as a complete and operational system. This will include operation of all valves, pumps, blowers, analyzers, alarms, meters, interlocks, monitors, level and pump controls, sensors, switches, off gas destruct equipment and all other equipment associated with the AOP system. Complete testing prior to leak testing and written notification provided to the Contracting Officer stating the equipment is working in accordance with the contract documents and manufacturer's recommendations prior to the commencement of leak testing.

3.11.2 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. All leaks are to be repaired and the system retested until no leakage is detected. Do not introduce ozone into the system until all leaks have been identified, repaired, and the system retested. [Diffusers] [Injectors] are to be installed in accordance with the suppliers recommendations. After installation, the [diffusers] [injectors] are to be covered with clear water to a depth of approximately [1] [_____] m [3] [_____] feet. Dry air or oxygen must be released through the [diffusers] [injectors] and the system are to be inspected for uniform air or oxygen distribution throughout the reactors. Following the initial testing at [1] [_____] m [3] [_____] feet, the distribution testing must be repeated at a water depth of [3] [_____] m [9] [_____] feet to ensure bubble distribution is adequate throughout the reactor. [Diffuser] [Injector] replacement or repositioning must be accomplished as required to maintain uniform air distribution throughout the reactor. If after repositioning, air distribution throughout the reactor lacks uniformity, additional redistributors or deflectors are to be installed in the reactor as recommended by the [diffuser] [injector] supplier to accomplish uniform flow distribution throughout the reactor.

3.11.3 Leak Testing

Leak testing must be accomplished at the factory to verify the integrity of the reactor vessels and associated gas and liquid piping. The factory leak test are to be accomplished on the reactor vessel and appurtenances following assembly at the factory. Onsite hydrostatic leak testing will include all piping between the upstream and downstream processes, and be accomplished using potable water at a pressure 1.5 times the working pressure, or 350 kPa 50 psi unless otherwise approved by the Contracting Officer. The reactor vessel and appurtenances are to be isolated from the connecting piping and retested for leaks using potable water following assembly at the site. The ozone generator gas connections are to be tested with dry air or oxygen at the maximum pressure allowed by the manufacturer, or as identified in the previous paragraph. Any gas or liquid leaks identified during the aforementioned testing must be repaired and the system retested until the systems are free of leaks.

3.11.4 Control Panel

A local control panel functionality test are to be performed and approved by the Contracting Officer prior to commencement of leak testing or testing using oxidizers. The central control testing must be accomplished prior to overall plant startup.

3.11.5 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.

****

The ozone generation system must be tested to ensure that the actual ozone production, power usage, or water consumption rates meet recommended requirements. Power usage must be measured after achieving steady state conditions as determined by the ozone generator supplier. Power usage must be measured 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. Power usage must be 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. Power usage must also be evaluated at 25, 50, and 75 percent of the design production rate.

3.12 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, or for startup or demonstration.

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 equipment specified, for a minimum of [3] [_____] days to supervise the installation, adjustment, testing, and to provide instruction in the operation, and maintenance of the equipment. If major components from multiple suppliers are provided, such as an [ozone generator] [air preparation system] [oxygen preparation system] [ozone destruct system] [_____], each supplier isrequired to visit the site a minimum of [1] [_____] times during equipment installation or startup. During the startup and [one] [_____] years operating period, the major equipment suppliers are required to be onsite [2] [_____] times to verify that the equipment is installed and operates properly, and to provide trouble shooting and technical assistance.

3.13 FIELD TRAINING

Provide a field training course for designated operating and maintenance staff members. The training will include 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. Training will be provided during normal working time and will start after the system is functionally complete but prior to performance testing. Field training must cover all of the items contained in the operating and maintenance manuals. Each major equipment vendor including, but not limited to, the ozone generator, ozone destruct system, ozone monitoring system, and gas feed system is required 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.

3.14 MAINTENANCE

3.14.1 Extra Materials

****

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.
****

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, the vessels storing consumables such as LOX, hydrogen peroxide [and] [_____] are to be refilled within [two] [five] days prior to the plant turn over.

3.14.1.1 Lamps

Provide a complete set of lamps reserved for change out by the equipment supplier following the one year warranty period. This extra set of lamps are to be delivered to the treatment facility 60 days prior to the end of the one year warranty period and installed by the Contractor. Lamp replacement during the one year warranty period is to be provided by the supplier, as needed by the Contractor.

3.14.1.2 Spare Parts

The supplier must provide, in addition to the lamps specified above, 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

3.14.2 Maintenance Service

****
NOTE: Delete this paragraph if UV lamps are not used. The designer may want to provide additional information regarding lamp change out if the system is limited to a certain lamp type. Medium pressure lamps have an approximate life of 3 to 4000 hours, while low pressure lamps have an approximate life of

7 to 10000 hours; certain proprietary, high intensity lamps may have a life less than 2000 hours.
****

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. Lamps and ballasts supplied as specified below, are to be provided in addition to the complete set supplied for installation (following the warranty period) and those installed as needed during the warranty period. The ozone generator dielectrics are to be cleaned 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.

3.14.3 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. The instructions are to include drawings and schematics of the system as installed. The instructions are to include the manufacturer's name, model number, service manual parts list and brief description of all equipment and their basic operating features. The instructions are to include, 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 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 --