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Design Requirements for the Supercritical Water Oxidation Test Bed

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MASTER

Design Requirements for the Supercritical Water Oxidation Test Bed

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ABSTRACT

This report describes the design requirements for the Supercritical Water Oxidation (SCWO) test bed that will be located at the Idaho National Engineering Laboratory (INEL). The test bed will process a maximum of 50 gph of waste plus the required volume of cooling water. The test bed will evaluate the performance of a number of SCWO reactor designs. The goal of the project is to select a reactor that can be scaled up for use in a full-size waste treatment facility to process U. S. Department of Energy mixed wastes. EG&G Idaho, Inc. will design and construct the SCWO test bed at the Water Reactor Research Test Facility (WRRTF), located in the northern region of the INEL. Private industry partners will develop and provide SCWO reactors to interface with the test bed. A number of reactor designs will be tested, including a transpiring wall, tube, and vessel-type reactor. The initial SCWO reactor evaluated will be a transpiring wall design.

This design requirements report identifies parameters needed to proceed with preliminary and final design work for the SCWO test bed. A flow sheet and Process and Instrumentation Diagrams define the overall process and conditions of service and delineate equipment, piping, and instrumentation sizes and configuration. Codes and standards that govern the safe engineering and design of systems and guidance that locates and interfaces test bed hardware are provided. Detailed technical requirements are addressed for design of piping, valves, instrumentation and control, vessels, tanks, pumps, electrical systems, and structural steel. The approach for conducting the preliminary and final designs and environmental and quality issues influencing the design are provided.

SUMMARY

U.S. Department of Energy (DOE) sites are generating and/or storing wastes contaminated with both radioactive and hazardous constituents. These mixed wastes cannot be disposed by current conventional means, such as incineration, landfills, and deep burial. DOE has directed that technologies be developed for the successful treatment of mixed wastes and that facilities be designed and developed for changing the waste into a form that can be legally and inexpensively disposed. One of the technologies being investigated for treatment of mixed waste is Supercritical Water Oxidation (SCWO). This process destroys the organic content of mixed wastes by injecting into a reactor a mixture of water and waste that is pressurized and heated above the critical point of water. Pure oxygen is also injected into the reactor to oxidize the organics. Depending on the waste, small quantities of inorganic radioactive material and salts may remain after processing.

SCWO is in an early stage of technical development. The primary challenge is to attain desired destruction efficiencies while limiting corrosion of plant components. The most important component of the SCWO process is the reactor. Several innovative reactor concepts currently being considered for development include a transpiring wall reactor, tubular reactor, and vessel-type reactor. Each of these designs attempts high destruction efficiencies and limits corrosion of the reactor walls and internals.

DOE has committed to building a test bed that will be used to test and develop various SCWO subsystems and components. The test bed will be located at the Idaho National Engineering Laboratory (INEL), Water Reactor Research Test Facility (WRRTF) and will process a maximum of 50 gph of waste. Of the 50 gph, a maximum is 10% waste, and the remainder is water. The test bed will be capable of running continuously for up to 100 hours. The test bed shall be designed to operate for a total of 17,000 hours over a 5-year period. The primary purpose of the test bed and testing efforts shall be to evaluate the operating characteristics of various reactor designs, subsystems, and other components.

This report contains detailed requirements for the engineering and design of the test bed, which will be performed by EG&G Idaho, Inc. Reactor design will be provided by private industry. The test bed shall consist of a deionized water subsystem; water heating and pressurization subsystem; waste mixing, pressurization and heating; oxygen pressurization; interfaces to a reactor; several phases of pressure and temperature let down; gas containment and emission; and disposal of the reactor effluent.

The deionizing water system shall be sized to produce and store adequate quantities of clean water that will be used to mix with waste, as mixing water to the reactor, and as cooling water. Based on the quantity and BTU content of waste to be processed, a maximum of 400 gph of water will be required with a storage capacity of 5,000 gal. The waste mixing process involves combining clean water with wastes to simulate the types of constituents that would be present in DOE mixed waste. The waste and water is mixed with a paddle mixer in two tanks. After mixing, the waste is pressurized by a pump to between 3,500 and 4,500 psig and then brought to temperature (ambient to 572°F) by a direct current electric heater. After heating, the waste is injected into the reactor. Clean water from the storage tank is also injected into the reactor. The clean water is also pressurized to between 3,500 and 4,500 psig and is heated to between ambient and 1,250°F. Gaseous oxygen (GOX) is added to the reactor at a maximum rate of 70 SCFM, which is based on a maximum requirement of three times the stoichiometric oxygen required for the waste. GOX is supplied from a liquid oxygen (LOX) storage tank and vaporizer, which are sized to supply about 150 hours of GOX at the maximum usage rate of 70 SCFM. LOX vaporizes at about 60°F. An accumulator is required to ensure that an adequate volume of oxygen is available for the planned testing if the vaporizer fails. The accumulator is sized to supply about 1 hour of GOX at 70 SCFM, pressurized to a maximum of 6,000 psig. The accumulator will maintain a pressure in excess of about 1,000 psig of the reactor's normal operating pressure to ensure waste from the reactor does not enter the GOX

system. After oxidation in the reactor, cooling water supplied from the deionized water system is added to help reduce the temperature of the fluid. Effluent is transferred from the reactor to the first stage liquid and gas separation vessel, which is sized to handle about twice the maximum flow from the reactor for a duration of 6 minutes, and normally operates from 3,500 to 4,000 psig. Gas is separated from the liquid in the vessel and then travels through a series of orifice plates that reduce the pressure to 1,000 psig, through a control valve that drops the pressure again to 250 psig, and then into a cyclone separator that removes particulates and liquid from the gas. The gas is routed through a series of filters that collect any remaining harmful constituents. The gas is then vented to atmosphere. The liquid from the first stage separator may be cooled by adding water in the vessel. The liquid continues through a series of orifice plates that reduce the pressure to 3,000 psig. A control valve further reduces the pressure from 3,000 to 1,500 psig. The liquid is sprayed into a second stage separation vessel, which is designed to remove remaining gas from the liquid. The second stage separator vessel shall be sized to hold twice the maximum flow (400 gph) from the first stage separator for a period of 1 1/2 minutes. The normal operating pressure is 50 psig and 500 psig for an upset condition. Effluent is sprayed on the walls of the second stage separator to liberate gases from the fluid. Gas from the second stage separator is routed to the gas filtering system, and liquid effluent passes through a solids separation filter and then to a storage tank. A sample is obtained from the storage tank to determine if the liquid is hazardous or nonhazardous. If the sample is determined to be hazardous, the liquid from the storage tank is routed to an evaporator that boils off the free liquid, and the remaining sludge will be collected and disposed in accordance with Resource Conservation and Recovery Act (RCRA) guidelines. Other hazardous solids collected from the test bed separators and filters will also be disposed in accordance with RCRA. If the liquid in the storage tank is nonhazardous, it will be disposed through a drain to an existing evaporation pond.

The test bed shall be designed using standard industry codes and regulations that govern engineering, fabrication, and construction of components such as piping, pressure vessels, tanks, instruments, structural steel, and electrical. For safety and environmental purposes, the high pressure systems of the SCWO test bed will be located in the north pit in Test Area North-646 at WRRTF, which is a concrete pit about 30 ft deep. All operations shall be performed remotely so personnel will not be in contact with any of the equipment. Provisions for on-line, continuous sampling shall be allowed for in the design of the hardware, so samples may be obtained in a safe manner while the test bed is operating. Other safety, quality, and administrative issues influencing the design of the plant are addressed in this report.

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ACRONYMS

ac	Alternating current
AI	Authorized Inspector
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASNT	American Society for Nondestructive Testing
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CMRR	Common Mode Rejection Ratio
CMTR	Certified Mill Test Report
dc	Direct current
DOE	U.S. Department of Energy
F&OR	Functional and Operational Requirements
GOX	Gaseous oxygen
HVAC	Heating, ventilating, and air conditioning
INEL	Idaho National Engineering Laboratory
I/O	Input/output
LAN	Local Area Network
LOX	Liquid oxygen
MCC	Motor Control Center
NASA	National Aeronautics and Space Administration
NEC	National Electric Code
NEMA	National Electric Manufacturer's Association
NEPA	National Environmental Policy Act
NESC	National Electric Safety Code
NFPA	National Fire Protection Association
PFI	Pipe Fitters Institute
P&ID	Process and Instrumentation Diagram
RCRA	Resource Conservation and Recovery Act
SAW	Steam, air, and water
SCWO	Supercritical Water Oxidation
SOW	Statement of Work
SSPC	Steel Structures Painting Council
TOC	Total Organic Carbon
UBC	Uniform Building Code
UL	Underwriters Laboratories
WRRTF	Water Reactor Research Test Facility

Design Requirements for the Supercritical Water Oxidation Test Bed

1. INTRODUCTION

1.1 Background

To support the development of a full-scale Supercritical Water Oxidation (SCWO) mixed waste plant for treating U.S. Department of Energy (DOE) mixed wastes, a 50 gph SCWO test bed shall be constructed at the Idaho National Engineering Laboratory (INEL). The SCWO process destroys organic constituents in DOE mixed waste in a cost effective manner. To date, there have been several bench and pilotscale plants built, and a limited number of waste types processed. The proposed pilotscale plant shall be capable of evaluating SCWO subsystems and components for a variety of simulated waste types that are representative of DOE mixed wastes. Primary benefits derived from the test bed include demonstrating the efficiency and cost effectiveness of several SCWO reactors, components, and subsystems; obtaining engineering data to use in the design of a SCWO Mixed Waste Pilot Plant; and answering key questions about waste throughput, construction materials, deposition, and corrosion related to different wastestreams.

While the SCWO process has been studied for some time, only recently has the technology been evaluated for large-scale treatment applications. Waste, an oxidant such as oxygen, and water are elevated to approximately 3,000 to 5,000 psig and temperatures above 705°F. The three streams are mixed based on the required energy content and oxygen balance. Oxidation occurs inside the reactor, and the temperature reaches a maximum of nearly 1,800°F depending on the fuel content of the waste. This process usually takes place in a chemical reactor, which thoroughly mixes the waste, water, and oxidant and optimizes the destruction of organic material. The selected temperatures and pressures represent conditions that, at this time, are thought to be optimal in the destruction efficiency of organics and in minimizing corrosive effects of the oxidation process. After oxidation, the mixture is cooled and condensed to a solid/liquid/gas effluent. The effluent is then separated and transferred to either an evaporator, where the remaining water is boiled off, or to an evaporation pond.

This report establishes design parameters that will be used for sizing components, locating and configuring hardware, selecting materials, providing process control, and ensuring that adequate safety and environmental design features are incorporated into the finished product.

Exceptions to requirements identified in this report, the project Functional and Operational Requirements Document (F&OR-232),¹ codes, standards, or other related project or technical documentation shall be identified to the program manager before design work proceeds.

1.2 Definitions

The following are definitions for terms used throughout this requirements document:

- **Cooling water**—Water that is added to cool waste and reactor mixing water after oxidation.
- **Deionized water**—Water that has had ions of dissolved salts removed.
- **Effluent**—Liquid and gas that remain after oxidation and cooling.
- **Gaseous Oxygen**—Gaseous oxygen (GOX) that is added to the SCWO process to provide adequate oxidation of organic material in the waste.
- **Neutralizing agent**—Chemical that neutralizes acids in the reactor effluent.
- **Program**—Organization with overall responsibility for the SCWO test bed design, facility design and modifications, operational concerns, safety and hazards analysis, project management and interface with the DOE customer.
- **Project**—Organization responsible for designing the SCWO test bed.
- **Raw water**—Water supplied directly from the existing WRRTF potable water system (i.e., no specialized treatment).
- **Reactor mixing water**—Heated water that is mixed with the waste.
- **Supplemental fuel**—Hydrocarbon-based fuel that will be added to wastes to provide adequate BTU content for oxidation.
- **Waste**—Simulated waste constituents such as salts, hydrocarbons, heavy metals, chlorides, and water.
- **Waste constituents**—Undiluted materials such as salts, hydrocarbons, heavy metals, and chlorides.

2. SCOPE

The scope of work covered by this report includes the following:

- Engineering, design, and analysis of all piping, vessels, valves, instrumentation, control systems, equipment, and structural supports for a 50-gph SCWO test bed to be located at the WRRTF, Building 646. Systems included in the design are low pressure waste mixing, high pressure waste delivery, high pressure mixing water supply to reactor, low and high pressure cooling water, oxygen storage and supply, separation of waste effluent, an effluent evaporation system, utility cooling water, a gas emission system, and a control and data acquisition system.
- Design of power distribution from an existing power source to equipment, lighting, and instrumentation. Design of emergency lighting and an uninterrupted power source to supply power for emergency lighting and safe test bed shut down.
- Piping, vessel, and equipment insulation and line marking and identification.
- Sampling lines and instrumentation, routing of instrument air tubing, purge lines, raw water lines, safety monitoring devices for oxygen, and flammable gases.
- Routing control cabling from the test bed to a remote control room located near Test Area North-646, north pit.
- Development of a cleaning specification to ready the system for start up.
- Design of structural steel platforms, ladders, stairways, covers, handrails, concrete pads, and retaining walls required to support test bed equipment (does not include facility modifications).
- Interface with the reactor, first stage separator, and deionized water supply system.
- Procurement of long lead material items.
- Preparation of Site Work Releases for fabrication and construction of SCWO test bed.

The work excluded from the scope of work includes the following:

- Design of the reactor, reactor instrumentation, insulation, and reactor structural supports.
- Design of the first stage liquid and gas separator vessel, instrumentation, insulation, and structural support.
- SCWO process system modeling.

- Preparation of National Environmental Policy Act (NEPA), or other environmental submittals, or hazards analysis submittals (including any safety analyses, emergency operation procedures, and safety plans).
- Determination of the final disposal method for any hazardous wastes produced during the testing of the SCWO test bed.
- Inspection, testing, upgrading, replacement of components of the existing WRTTF deionized water supply system, work required to bring the deionized water system up to current operating, and safety standards.
- Demolition and/or removal of structural steel, piping, asbestos insulation, cable, wire, conduit, electrical and instrumentation equipment and other materials (i.e., nonhazardous and possibly hazardous) located in the north pit at WRTTF (i.e., the area proposed to locate the SCWO test bed). Removal of cable, cable tray, piping, and equipment on the main floor area that may be needed to locate low pressure mixing and storage systems for the SCWO test bed. Removal of equipment, cable, wire, cable tray, or other components from the steam, air, and water (SAW) control room in Building 646.
- Design and installation of any architectural or building system changes or additions to meet safety, environmental, or access requirements.
- Architectural work including office, laboratory or control room renovation, phones, Local Area Network (LAN), furniture, and laboratory fixtures.
- Upgrades to, or addition of, new building utility and safety systems, which include power, heating, ventilating, and air conditioning (HVAC), water, fire protection, air, laboratory gases, laboratory vents, drains, and alarms.

Deliverables for this design task include the following:

- Drawings
- Specifications
- Engineering Design Files documenting the analysis, approach, calculations, and assumptions for the SCWO test bed design.
- Procurement requisitions for long lead material items and preparation of a Statement of Work (SOW) to acquire materials and subcontracted services for construction, assembly, and testing of the SCWO test bed.
- Preparation of Site Work Releases for fabrication of SCWO test bed components.

3. GENERAL REQUIREMENTS

3.1 General Facility and System Requirements

3.1.1 Test Bed Facility Interface

The following are requirements for the facility that will contain the SCWO test bed. Providing for these facility requirements is the responsibility of the program and is beyond the scope of the SCWO test bed design.

- The SCWO test bed shall be located indoors (some equipment will be located outdoors as specified in this document) in an area that provides adequate space (i.e., approximately 3,600 ft²); is well lighted, heated, and ventilated; has necessary fire protection and alarm systems, phone and communication systems, adequate power availability (approximately 1,200 kW), and a deionized water supply (12 gpm); and meets requirements for industrial hygiene such as protection from hazardous materials, restrooms, and washroom facilities.
- The area where the test bed is located shall be accessible by an exterior doorway sized to accommodate a flatbed truck with a minimum vertical clearance of 16 ft. Through this doorway, equipment and materials shall be brought into the area by truck or other vehicles and unloaded and set into position. Overhead bridge cranes with a 5 and 50-ton capacity shall be available in the facility and shall be located so that there is complete access to load and unload vehicles and to the area where the test bed is located.
- The test bed shall be situated so that it can be operated remotely. While in operation, personnel shall be shielded in the event of a system rupture (i.e., no personnel shall be allowed near high pressure components of the test bed while in operation). In the event of a breach of system integrity, contaminated materials shall be contained and collected.
- The test bed shall be located in an area that is not congested with other system piping, cabling, structural steel, vessels, or materials and equipment that could (a) pose a threat to the safety and well being of personnel working on and around the plant, (b) pose a threat to the safe operation of the plant, and (c) create logistical problems in routing, installation, maintenance of SCWO test bed piping, equipment conduit, or cabling.
- The test bed shall not be located near other ongoing programs if activities of other programs interfere with test bed installation, operation, or testing activities, and likewise, the planned activities of the SCWO test bed shall not interfere with the operation of other programs.
- Storage area for hazardous materials and hazardous wastes shall be available.
- The area where the test bed is located shall be provided with adequate ingress and egress for normal access to perform construction, maintenance and inspection functions, collect samples, and related routine activities concerning installation and operation of the plant. Likewise, adequate ingress and egress shall be provided in the facility for emergency conditions.
- The facility shall have the capability to dispose of clean, raw cooling water and nonhazardous process effluent generated during testing.

- The facility shall offer office space for 10 people. Offices shall be adequately sized and provided with phones and LAN access. Area shall be available for the test bed control room, a laboratory and analysis area, and storage room. The control room shall be approximately 150 ft² and provided with a phone and LAN access. There shall be adequate space in the control room for locating a CRT, personal computer, recording and data acquisition equipment, and other related remote control equipment. It is anticipated that the required equipment shall fit on two standard table tops. An office or room with about 400 ft² of space shall be furnished to serve as a field laboratory and analysis area. The laboratory area shall be provided with a phone, LAN, special laboratory fixtures (see Section 3.8.11), and furniture. An area of approximately 150 ft² shall also be required for storage of test bed materials, consumables, tools, and other items.

3.1.2 Process System

A brief description of the required SCWO process systems is provided below. Figures 1 and 2 provide SCWO flow sheets of the SCWO process. A more complete description of the operating requirements for pressure, temperature, flow rates, components, and construction materials are described in Section 4 "Specific Requirements." The test bed shall be sized to handle a maximum of 50 gph of waste, with a continuous processing capability of 100 hours.

- **Deionized Water Supply**—This system shall deionize sufficient quantities of water for mixing with waste constituents, cooling water, and reactor mixing water. A maximum of 50 gph shall be required to supply the waste mixing and reactor mixing water systems. Three hundred and fifty gallons per hour is required to supply the cooling water system. The system shall consist of deionizing columns sized to handle the required volume of water, storage for sufficient capacity of water used during a 100-hour test, and a low pressure pump to deliver water to the mixing system. The existing deionized water system at WRRTF will be refurbished and used to provide water to the test bed. Refurbishing the existing deionized water system shall be performed by the program and is beyond the scope of design for the SCWO test bed. Note: The chemical purity of the water shall be defined by the program and is beyond the scope of this document.
- **Waste Mixing and Storage**—The deionized water supply system mixes deionized water with desired quantities of waste constituents to a homogeneous (or nearly homogeneous) fluid. The system includes startup fuel for initiating oxidation and establishing a temperature profile inside the reactor. Two waste mixing tanks shall be required so that while waste is being pumped from one tank to the reactor, the other may be used to mix waste constituents with water. The tanks shall be sized so that the combined volumes shall supply a continuous, 10-hour test (without refilling or additional mixing). A paddle-type mixing blade is used to homogenize the waste constituents and water. The paddle blade shall be sized so that the waste constituents and water mix can be homogeneously blended within 1 hour after the tank is filled. Waste shall be pumped from the tanks by a high pressure pump.

PRELIMINARY FLOW DIAGRAM
FOR SCWD TEST BED
SUPPLY SYSTEM

Figure 2. SCWO flow sheet 2.

- **High Pressure Waste Delivery and Heating**—The waste shall be elevated to an operating pressure of 3,500 to 4,500 psig with a high pressure pump, and depending on the reactor configuration and test requirements, heated before introduction into the reactor. A high pressure, variable speed pump capable of delivering 0 to 50 gph of waste to the reactor shall be used to pressurize the wastestream. Once at pressure, the wastestream can be passed through a direct current (dc) heater, and heated to between ambient and 572°F before injection into the reactor.
- **High Pressure Mixing Water Supply to Reactor**—Clean water from the deionized water storage tank is pressurized with a high pressure pump, heated to the desired temperature (depending on the reactor configuration and specific test requirements), and injected into the reactor. A variable speed pump capable of 0 to 50 gph shall be used to bring the pressure of water to an operating pressure of 3,500 to 4,500 psig. The water is heated to between ambient and 1,250°F.
- **High Pressure Reactor and First Stage Separator Cooling Water**—Depending on the specific reactor and testing configuration, deionized water shall be used to cool the reactor effluent by means of heat exchange, or direct injection and mixing with the effluent in the reactor, the first stage separator, or a combination of both vessels. A maximum of 350 gph of cooling water is required at an operating pressure between 3,500 to 4,500 psig to cool the effluent to between an operating temperature of 392 and 482°F. If a heat exchanger is used to cool the effluent, then the design for this equipment shall be provided by the reactor designer.
- **LOX and GOX Storage and Supply**—A sufficient quantity of liquid oxygen (LOX) shall be stored to support 150 hours of testing, allowing for a maximum requirement of 70 SCFM of GOX injected into the reactor. The LOX/GOX storage and supply system shall consist of a storage tank for LOX, a LOX to GOX vaporizer, and a GOX accumulator (sized to supply 70 SCFM of GOX at an operating pressure of 5,000 psig). The accumulator shall be designed for 6,000 psig so there is overpressure available in the system to supply 1 hour of GOX to the reactor if the vaporizer pump fails.
- **Reactors**—The reactors shall be supplied by private industry. Each reactor shall consist of a vessel and piping arrangement sized to accommodate the combined flows of the waste mixture, supercritical water, GOX, and cooling water (for each reactor design, the quantities of these constituents may vary). The reactor will oxidize the organics in the wastestream with a destruction efficiency of 99.99% while limiting deposition. Initially, a transpiring wall reactor will be evaluated in the test bed. Other reactor designs, including a tubular and vessel, will be evaluated.
- **First Stage High Pressure Separation**—A vessel shall be provided by the reactor designer and fabricator to serve as the first stage for gas and liquid separation. The reactor and first stage separator must be designed to work as an integral unit, ensuring proper cool down of the reactor effluent, limiting corrosion, and separating liquid and gas. It shall be sized to handle twice the maximum effluent and gas discharge from the reactor for a period of 6 minutes, with 50% of the vessel volume occupied by liquid and 50% occupied by gas. Gas from the separator shall be vented to an emission system after pressure let down. The effluent from the first stage separator is reduced in pressure and sprayed into the second stage separator.

- **Second Stage High Pressure Separation**—Liquid from the first stage separator is transferred into the second stage separator. The pressure is reduced between the two separation vessels, and the effluent is sprayed on the interior walls of the second stage vessel to promote further separation of the gas from the liquid. Gas from the second stage separator is routed to an emission system. Fluid from the second stage separator is placed in a storage tank, and after sampling is either evaporated in a pond or boiled off. The second stage separation vessel is sized to accommodate twice the maximum flow rate of fluid volume from the first stage separator for a period of 1 1/2 minutes.
- **Gas Emission System**—Gas from the first stage separator is initially let down from a normal operating pressure of 4,000 to about 250 psig and then flows through a cyclone separator to remove any solids or liquid carry over. The gas is then reduced to near atmospheric pressure and released to atmosphere after filtering. Gas from the second stage separator is also filtered and released. Gas vented to the atmosphere shall meet applicable emission standards.
- **Effluent Disposal**—Liquid from the second stage separator is first passed through a filter to remove suspended solids and then placed in holding tanks. A sample is taken from the holding tank to determine if the liquid is hazardous or nonhazardous. If the liquid is hazardous, it is boiled off by a dc electric evaporator sized for the maximum expected volume of effluent per hour (50 gph of waste plus cooling water). Any remaining sludge or solids from the evaporator are disposed as Resource Conservation and Recovery Act (RCRA) wastes. If the sample from the holding tank indicates the fluid is nonhazardous, it is routed to an existing drain line and evaporation pond.
- **Miscellaneous Systems**—Other utility systems needed to support the overall process include utility cooling water, nitrogen purge, and instrument air.

3.1.3 Waste Composition

A series of DOE simulated wastes have been defined for DOE SCWO testing and selected to cover a wide spectrum of constituents that could be introduced into a mixed waste plant.

- Series 1. Aromatics with mercury
- Series 2. Nonchlorinated solvents with metals
- Series 3. Paper, cloth, and plastic
- Series 4. TRIM[®]SOL
- Series 5. Mixed oils
- Series 6. Activated carbon

- Series 7. Scintillation fluid
- Series 8. Tributyl phosphate

Each selected series represent mixtures and concentrations of hydrocarbons, heavy metals, salts, and radioactive surrogates. The composition of each series is given in F&OR-232, "Supercritical Water Oxidation Test Bed Functional and Operational Requirements." A detailed discussion about the selection process and each of the wastes is given in *Mixed Waste Survey for Supercritical Water Oxidation Program*.² The test bed shall be designed for processing all the test wastes, with the highest priority on the first four.

For design purposes, the following boundary conditions shall be observed relative to waste composition:

- The maximum concentration of waste constituents per 50 gal of waste and reactor mixing water is 10%. For the eight series of waste, TRIM®SOL is the most corrosive; although at ambient conditions, it has not caused excessive corrosion when in contact with stainless steel (based on observations from existing SCWO test beds). Likewise, after heating the waste and before entering the reactor, there have been no reported corrosion problems with TRIM®SOL and stainless steel in operating SCWO test beds.
- For the effluent, the most corrosive condition expected is hydrochloric acid, which will be formed from chloride contained in Series 4, TRIM®SOL. It is planned to neutralize the acid, and the minimum pH expected is 2. For design purposes, it is assumed that the addition of a neutralizing agent will neutralize 80% of the acid for any series of waste containing acid. The remainder of the acid would be concentrated in the effluent at a maximum level of 1,500 ppm. This concentration is in pure effluent and assumes no cooling water is added, so the estimate is conservative.
- Series 2, nonchlorinated solvents with metals, shall be used as the design basis for maximum particulate concentration in the waste feed and effluent. Maximum particulate size allowed in the reactor is 100 microns. A total of 2,200 ppm of undissolved solids (assuming no dilution from the cooling waterstream) would be the maximum amount contained in the waste feed. For the effluent, maximum undissolved solids will be assumed to be the amount present in the waste feed (i.e., 2,200 ppm) plus any solids generated by corrosion. A conservative estimate for the maximum quantity of undissolved solids in the effluent is 4,400 ppm.

A study shall be conducted to determine the maximum allowable particle size in effluent from the first stage separator (i.e., it may be necessary to place a cyclone separator or filter just downstream of the first stage separator to remove certain particulates and limit erosion and plugging of downstream system components).

3.1.4 Service Life

The SCWO test bed shall be designed to operate continuously up to a 100-hour duration run. Most testing will be 10 to 20 hours in duration. Seventeen thousand hours of on-stream service operation over a 5-year period shall be the basis for the design life. The test bed will operate a maximum of 4,000 hours/year. A total of 500 cycles, including startup, normal operation, and shutdown, shall be the basis for components

requiring cyclic analysis (such as piping, vessels, pumps, valves, and instruments) and subjected to cyclic loading conditions.

The equipment and components used in the test bed shall be subjected to conditions promoting excessive wear and corrosion. As a result, materials used in the construction of the test bed shall be (a) selected for resistance to the expected operating environment, and (b) located so that they may be easily accessed for inspection, repair, and when necessary, replacement. For components that may be subjected to excessive wear and corrosion, it may be required to provide for redundant design, which could include dual piping runs, valves, instruments, and vessels.

3.1.5 Environmental Conditions

The SCWO test bed equipment shall be installed indoors in a controlled environment and protected from the weather, with the exception of the oxygen supply system, effluent storage tanks, and evaporator. All SCWO test bed systems shall incorporate features needed for satisfactory operation under the following environmental conditions:

Altitude of SCWO test bed	4,600-ft mean sea level
Average barometric pressure	25.06 in. of mercury
Operating ambient temperature range	+50 to 85°F (for equipment located indoors) -45 to 100°F (for equipment located outdoors)
Humidity	0 to 80% plus condensation
Annual precipitation	10 in.

3.1.6 Reliability

Components for the SCWO test bed shall be selected to minimize failures. When equipment, instruments, and mechanical and electrical components of the plant are properly maintained and inspected over the specified service life of the plant (i.e., 17,000 hours spread over 5 years), there should be virtually no component failures. This does not preclude the replacement of parts or scheduled maintenance for items but reinforces the need to judiciously select materials that do not fail under normal use and test operation.

Emphasis shall be placed on selecting equipment and instruments that can operate reliably over the required service life. Selection of items shall involve checking with vendors and suppliers to verify that a particular item is suitable for the intended hours of operation under the specified conditions. This may entail (a) documented operational history of the item, (b) documented Mean Time Between Failure testing or another recognized method of testing to verify reliability, and (c) reasonable assurance that predecessor models have operated to the stated standards of reliability for new products or new generations of existing items manufactured without reliability testing.

3.1.7 Procurement of Materials and Services

As part of the design effort for the SCWO, several SOW and material requisitions shall be prepared as deliverables for the preliminary and final designs. These documents shall be prepared in a manner that is acceptable to EG&G Idaho procurement. Materials, services, subcontracts, and other acquired items obtained for the SCWO test bed through EG&G Idaho procurement shall be in accordance with the procedures contained

in Section 3 of the *Company Procedures Manual*.³ These procedures include instructions for preparing a SOW, quality assurance guidance for certain materials used in high pressure/high energy applications, ordering information for suspect bolting materials, and obtaining material safety data sheets and other guidelines that affect the preparation of material and service requisitions for the SCWO test bed.

Some equipment and material items may, in support of the overall program schedule, have to be procured early during the design phase. It is anticipated that the pressure vessels and control valves will be long lead procurement items and purchased by EG&G Idaho. Other material and equipment items that are considered long lead procurements shall be identified during the preliminary design. A list of long lead procurement materials and equipment shall be identified and maintained by the project, and requisitions for the materials shall be prepared and submitted to procurement.

3.1.8 Corrosion

Highly corrosive compounds will be present in the SCWO test bed effluent. A technically justified corrosion allowance shall be specified to determine the minimum required wall thicknesses of each system component to allow for general corrosion. The corrosion allowance shall be determined by evaluating known data relative to the corrosion rates of materials subjected to process conditions similar to those expected for the SCWO test bed. Stress corrosion cracking is also a key design concern. Materials and component geometry shall be selected to prevent or mitigate the effects of stress corrosion cracking. For additional information on this aspect of the design, refer to Reference 4, *Corrosion in Supercritical Water Oxidation Systems: Workshop Summary*.

3.2 Codes and Standards

The following codes and standards shall be used to the extent applicable. The current issue of the specification in effect on the date when the requirements document is issued shall apply.

- Facility-Structural, Concrete, Architectural
 - Structural Steel
 - American Institute of Steel Construction (AISC)—Code of Standard Practice for Steel Buildings and Bridges
 - AISC—Detailing for Steel Construction
 - AISC—Specification for Structural Joints using American Society for Testing and Materials (ASTM) A 325 or A 490, Bolts
 - AISC—Quality Criteria and Inspection Standards
 - AISC—Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings

American Society for Nondestructive Testing (ASNT)—SNT-TC-IA, Personnel Qualification and Certification in Nondestructive Testing

ASTM—Various product form designations such as A 36 structural steel, A 325 high strength bolts for structural steel joints

Steel Structures Painting Council (SSPC)—Painting Specification

American Welding Society (AWS)—D1.1 Structural Welding Code

Uniform Building Code (UBC)

– Concrete

American Concrete Institute

– Architectural

UBC

• Mechanical Systems

– Piping

American National Standards Institute (ANSI)—B31.3, Chemical Plant and Petroleum Piping

American Society of Mechanical Engineers (ASME)—Section IX, Welding Qualifications

ANSI Standard B16.25, Butt Welding Ends

ANSI Standard B16.5, Steel Pipe Flanges, Flanged Valves, and Fittings

ANSI Standard B16.10, Face-to-face and End-to-end Dimensions of Ferrous Valves

ANSI Standard B16.34, Valves-Flanged and Butt Welding End

ANSI B16.104, American National Standard for Control Valves Leakage

ANSI Z88.2, Practices for Respiratory Protection

Pipe Fitters Institute (PFI) Standard ES-3, Fabricating Tolerances

PFI Standard ES-5, Cleaning Fabricated Piping

National Aeronautics and Space Administration (NASA)—NSTL 79-001, NSTL Facility Cleanliness, Appendix B: Requirements for Propellant, Gas, and Hydraulic Systems

Compressed Gas Association (CGA)—CGA G-4.4, Industrial Practices for Gaseous Oxygen Transmissions and Distribution Piping Systems

CGA G-4.1, Cleaning Equipment for Oxygen Service

CGA P-14 Accident Prevention in Oxygen-rich and Oxygen-deficient Atmospheres

NASA Reference Publication 1113, Design Guide for High Pressure Oxygen Systems

Military Specification 1246B, Cleaning for Oxygen Systems

National Fire Protection Association (NFPA)—Section 50, Standard for Bulk Oxygen Systems at Consumer Sites

ASTM—Various product form designations

— **Vessels**

ASME—Boiler and Pressure Vessel Code, Section VIII, Divisions 1 and 2

ASME—Section IX, Welding Qualifications

ASME—Section V, Nondestructive Examination

ASTM—Various product form designations

• **Electrical**

National Electric Manufacturer's Association (NEMA)

NFPA—National Electric Code, (NEC) NFPA 70

National Electric Safety Code (NESC)

Underwriters Laboratories (UL)

ASTM—Various product form designations

• **ANSI—Various requirements for materials used in electrical construction Instrumentation and Data Acquisition**

NFPA—NEC, NFPA 70

- Other Codes, Standards, and Orders

DOE-Idaho Operations Office *Architectural Engineering Standards*

EG&G Idaho *Architectural Engineering Standards*

DOE/EV-0132, "Environmental Compliance Guide"

DOE Order 5480.1B, "Environmental, Safety, and Health Program for DOE Operations"

DOE-STD-1020-92, "Natural Phenomena Hazards Design and Evacuation Criteria for Department of Energy Facilities"

DOE Order 6330.1, "General Design Criteria Manual"

Code of Federal Regulations (CFR) 29, Chapter XVII, Part 1910, "Occupation Safety and Health Standards"

NFPA *Life Safety Code Handbook*

Uniform Fire Code

EG&G Idaho *Safety Manual*

EG&G Idaho *Quality Manual*

3.3 Interface Requirements

3.3.1 Transpiring Wall Reactor

A transpiring wall reactor shall be provided by private industry and will be interfaced with the SCWO test bed. The transpiring wall reactor initially used in the SCWO process limits corrosion by using the transpiration-cooled technology. Clean water is injected around and along the inside of the reactor. The injected fluid forms a barrier between the walls and wastestream that prevents salts, particulates, or other corrosive materials from contacting interior reactor surfaces. The transpiring wall reactor shall be oriented vertically and fed on the upstream side by GOX, water, and wastestream. The first stage separation vessel shall be located on the downstream side of the reactor. Instrumentation for both control and data acquisition shall be located on the reactor.

For the transpiring wall reactor, the following process interfaces are assumed.

- Pressure, temperature, and volume of waste feed into reactor: 3,500 to 4,500 psig operating, 5,000 psig design, ambient to 572°F, and 0 to 50 gph

- Pressure, temperature, and volume of mixing water into reactor: 3,500 to 4,500 psig operating, 5,000 psig design, ambient to 1,250°F, and 0 to 50 gph
- Pressure, temperature, and volume of oxygen: 0 to 5,000 psig operating, 6,000 psig design, ambient temperature, and 5 to 70 SCFM
- Pressure, temperature, and volume of cooling water into reactor: 3,500 to 4,500 psig operating, 5,000 psig design, ambient temperature, and 0 to 350 gph
- Pressure, temperature, and volume of effluent exiting reactor into first stage separation vessel will be determined by the reactor vendor.

3.3.2 Tube and Other Reactor Configurations

Besides the transpiring wall reactor, several other SCWO reactor configurations (the tube and vessel designs) are being considered for testing in the proposed test bed. The design parameters of temperature, pressure, and flow rates for these other reactors are assumed to be within the boundaries established for the transpiring wall reactor. Fluid velocities and densities, composition of waste, and other process related characteristics may be varied. Limited technical information is available about these reactors so designing the test bed to completely accommodate the equipment is not feasible at this time. To the extent that information is available at the time design of the test bed is in progress, consideration shall be given to locating the tube and vessel reactors. It is assumed that the tube and vessel reactor designs will include heat exchangers that will be provided by the reactor vendor.

3.3.3 First Stage Separator

The reactor designer and fabricator shall also design and fabricate the first stage liquid and gas separation vessel. This vessel will be located at the base of the reactor and will hold approximately twice the volume of the maximum flow rate of effluent from the reactor (400 gph) for a period of 6 minutes. The bottom of the transpiring wall assembly from the reactor will be situated in the first stage separator. Liquid effluent from the vessel will be discharged at an operating pressure of 4,000 psig (design pressure 5,000 psig), maximum temperature of 482°F for acidic effluent, or 572°F for nonacid effluent, and at a rate of 150 to 400 gph. The pH of the liquid is expected to range between 2 and 7. The maximum suspended solid particle size is assumed to be 100 microns, and the maximum concentration of solids is 4,400 ppm. Liquid effluent from the vessel will be routed through a series of orifice plates and to the second stage liquid and gas separator. Gaseous effluent from the vessel will be discharged at an operating pressure of 4,000 psig (5,000 psig design pressure), 482°F for acidic effluent, or 572°F for nonacidic effluent, and at a rate of 1 to 30 ACFH. The expected pH will range between 2 and 7. Maximum solids concentration is 40 ppm.

3.3.4 WRRTF Interface

The SCWO test bed shall be located at WRRTF. The high pressure feed systems, reactor, and separation vessels shall be located in the existing north pit in the main high bay area of Building 646. The LOX storage tank, waste mixing, evaporator, and other low pressure systems shall be located either at floor level in the high bay or outside the building. For a detailed description of the existing WRRTF facilities, see Reference 5, *Site Development Plan, Site Characteristics*. Any work required to alter, upgrade, or modify the following

building infrastructure or systems and interfaces shall be performed by the SCWO program and is beyond the scope of the SCWO test bed design.

Specific interfaces between the existing WRRTF facility and the proposed test bed include the following:

- The test bed will be configured and arranged in the north pit. Much of the existing Semi-Scale equipment, piping, steel, tubing, and wiring in the pit shall be removed. Some of the fixtures and equipment shall be left in place (e.g., for high voltage power distribution). The project shall develop a model of the pit with any existing equipment left in place and interfaced with the new equipment to be installed. A CALMA 3-D model of the existing pit and facilities shall be developed as a part of the design effort.
- Some of the piping and vessels in the north pit are covered with insulating materials, including asbestos. The program shall determine if the asbestos-insulated equipment can be left in place and worked around. If it is left in place, it shall be shown on the 3-D model.
- An existing deionizing water system and storage tank shall be refurbished by the program for use with the test bed. The program shall make available to the project physical data about this system that are needed for proper interface with other SCWO systems. Flow rates, chemical composition of the water, pipe locations, materials, and sizes shall also be provided.
- Approximately 4 MW of electrical power are available for use at WRRTF. How power shall be routed to equipment in the test bed needs to be determined. An assessment shall be performed to identify the configuration and condition of the existing system and any upgrades or changes to safely operate the facility power and to determine how power for test bed equipment and lighting shall be supplied.
- A systems assessment of WRRTF building systems such as HVAC, emergency alarms, raw water supply, communications, fire protection, and any other building systems shall be made by the program to determine if (a) there is an interface with the SCWO test bed and (b) these facility systems are safe and operable to satisfy current INEL standards.
- There is at least one other ongoing program within Building 646 (explosives research work). This program and any other planned work within WRRTF shall be coordinated with the SCWO test bed program to ensure there are no potential safety, operational, or administrative conflicts.
- Upgrade of office, laboratory, control room, and storage space at WRRTF will be performed by the program. This includes adequate lighting, phones, LAN, partitions, furniture, and in the case of the laboratory, special safety fixtures such as a fume hood, exhaust vent and compressed air. For the proposed SAW control room, the program must determine if the existing single doorway provides adequate ingress and egress during normal and emergency operating conditions. Another doorway may be required, or it may be necessary to relocate the control room.
- General vehicle and construction access within WRRTF shall be investigated by the program to ensure there are no areas that could cause problems during construction and operations, such as undersized doorways, low clearances, or areas with poor visibility.

3.4 General Access for Construction, Operation, Maintenance, Testing, and Inspection

3.4.1 Valves and Instruments

During the design, care shall be used when specifying the location of valves and instruments in piping systems (and elsewhere) with respect to access and operation. The following guidelines shall be followed:

- During construction placement of valves (e.g., manual, control, and pressure relief) and instruments shall not be hampered by the routing of other systems or location of other equipment, and the position of the valve or instruments shall not interfere with installation of other systems. Consideration shall be given to high pressure valves or instruments that may be fabricated in several pieces for assembly in the field. Space shall be allowed around the valve or instrument for field installation of components (e.g., actuators). Also, space shall be provided for any special tools or equipment needed to install and clean the valve or instrument and for personnel to work.
- Manual valves shall be designed so that hand operators are easily accessible by personnel. Valves shall be located so that operators minimize stooping, bending, and reaching. Valves shall be positioned so they do not cause a hazardous condition to the operator and equipment. Valves shall be designed to minimize the potential for a hazard created by a drip or spill. Human factors shall be considered when positioning valves and hand operators.

Control valves and instrumentation shall be operated from a remote control room. Design of the remote operation features for each valve or instrument shall consider the function of the item, display data, control and operating data associated with the valve or instrument, interlocks with other systems, and alarm conditions.

- Adequate space to perform maintenance, testing, and inspection on the valves and instruments shall be provided. Valves and instruments shall be placed so that they are accessible for maintenance, including full removal or removal of integral components. Adequate space shall be provided for personnel and tools and to ensure that there are no interferences with equipment (e.g., piping). Access to perform testing, such as operational pretesting and pressure testing, shall be included in the design. Inspection access shall include providing space around the valve or instrument so quick visual inspections may be made and access to components is available.

Most valves and instruments for the SCWO test bed will be relatively small (i.e., less than 1 1/2 in.). However, because of the high pressure, the weight of the valve or instrument could be several hundred pounds. When locating valves larger than personnel can manually lift and handle (i.e., approximately 50 lb but may vary widely depending on ergonomics), special consideration shall be given to crane access or another means of rigging and hoisting valves for installation and removal.

CALMA 3-D modeling software will be used to design the SCWO test bed. A key feature of the software is the capability to define operating and maintenance envelopes for equipment, instruments, and valves and to determine if there are interferences within the envelope. For all valves and instruments, the following

shall be determined using the CALMA software: (a) limits of the operating and maintenance envelope, and (b) there are no interferences within the envelope.

3.4.2 Vessels and Equipment

The same guidelines discussed in Section 3.4.1 apply to vessels and equipment. Careful attention shall be given to providing vessels and equipment adequate physical space for initial installation, removal of the entire item or internal components for maintenance and inspection, operation of the equipment, and testing.

For safety reasons, the high pressure equipment shall be located in the north pit. Tentatively, it is planned that equipment shall be located at, or near, the floor of the pit, and a mezzanine shall be built about half way up the pit allowing for a second platform to locate equipment. Attention shall be given in locating equipment to provide overhead crane access during installation and in case the item has to be removed or relocated at a later date.

All equipment shall be modeled on the CALMA software, with an operating and maintenance envelope assigned, and an analysis made determining that no interferences exist.

3.4.3 Piping

As for valves, instruments, vessels, and equipment, access to piping during initial installation and subsequent maintenance and inspection shall be analyzed and provided in the design. It is probable that piping will be rerouted several times pending the configuration of the reactors, so clear access is important. Special attention will be placed on the design of oxygen system piping to allow frequent access for inspection, cleaning, and maintenance.

3.5 General Design Requirements for Pressure Vessels and Tanks

3.5.1 Design Requirements

Pressure vessels shall be designed, fabricated, inspected, and tested in accordance with ASME Section VIII Division 1. All pressure vessels shall be stamped and registered with the National Board.

Tanks may be custom designed and fabricated, may be pre-engineered, or existing tanks or vessels at the site that meet design requirements may be used. Materials other than steel (such as fiberglass) may be considered for service. A specification governing the design and construction of the tank shall be generated.

Table 1 lists the number of vessels and tanks and intended service for each.

The following design requirements apply for vessels and tanks:

- All vessels shall be designed so that shell and liner materials can be easily inspected for corrosion. In cases where liners are used, the vessel design shall make changing the liner as simple a task as practicable.

Table 1. Vessels and tanks for the SCWO test bed.

Description (pressures and temperatures shown are maximum design values)	Number required
Waste mixing and storage tank (600 gal, 15 psig, 100°F)	2
	2
Deionized water storage tanks (approximately 1,000 gal, 15 psig, 100°F): Use existing tanks located at WRRTF near deionizing columns	1
Reactor: Process conditions defined by the vendor	1
LOX storage vessel (6,000 gal, 275 psig, +100 to -350°F)	1
GOX accumulator(s) (total 54 ft ³ storage capacity, 6,000 psig, 100°F)	1
First stage separator: To be supplied by reactor vendor, process conditions defined by vendor	1
Second stage separator (20 gal, 500 psig, 572°F)	1
Deionized water storage vessel (3,000 gal, 150 psig, 100°F): Use existing storage vessel at WRRTF	2
Reactor effluent storage tanks (3,000 gal, 15 psig, 100°F)	

- All vessels and tanks shall be structurally supported to meet the UBC seismic design requirements for Zone 2b, importance factor of 1.25. All vessels shall be analyzed for dynamic loads that may be generated as a part of normal or upset operating conditions. Vessels and tanks located outdoors shall be analyzed for wind loading.
- All vessels and tanks shall be arranged and supported to allow for growth caused by thermal expansion and contraction.

3.5.2 Construction Materials

Materials for all vessels and tanks shall be selected to consider the following design parameters:

- Stress generated in the material as a function of pressure
- Temperature, thermal fatigue, thermal stress, and thermal transients
- Resistance to corrosion, stress corrosion cracking, and pitting
- Severity of service application
- Mechanical fatigue and creep
- Constructability and weldability.

An analysis shall be performed to ensure factors such as toughness, high pressure service, high and low temperature are considered before determining which material shall be used for fabrication of a vessel or tank. Full material certification as specified by ASME Section VIII is required for all pressure vessels. No dual or multiple certification for ASTM standard materials shall be allowed (i.e., only one material type shall appear on any material certification sheet).

3.5.3 Preparation of Procurement Specifications and Follow-on Inspection

Procurement specifications shall include information needed to issue a subcontract to a third-party vendor to proceed with design, fabrication, and testing of the long lead pressure vessels (i.e., second stage separation vessel, LOX storage tank, and GOX accumulators) as required for the SCWO test bed. The procurement specification shall be prepared in accordance with the EG&G Idaho *Specifications Preparation Manual*. A sketch indicating the dimensions of the vessels and location and size of nozzles and instrument ports shall be provided. Process information on design temperature and pressure, corrosion allowances, and environmental conditions shall be included in the specification. Construction materials and welding requirements shall also be specified. For pressure vessels, a detailed and thorough review of the ASME Section VIII code shall ensure that all parameters affecting the design and fabrication of a pressure vessel are identified in the specification. All design calculations shall be reviewed and approved by EG&G Idaho before fabrication. In the vendor's shop, a final inspection of the vessel shall be made by EG&G Idaho prior to shipment of the vessel. EG&G Idaho's Authorized Inspector (AI) shall review final code documentation packages for all pressure vessels prior to final acceptance and delivery of the vessel from the fabricator. EG&G Idaho's AI shall also inspect the vessels after delivery to the INEL and before they are put into service.

3.6 General Design Requirements for Piping Systems

3.6.1 Design Requirements

Piping for the SCWO test bed shall be designed in accordance with ANSI B31.3, "Chemical Plant and Petroleum Refinery Piping." Provisions for design and fabrication of piping contained in Chapter VIII, "Piping for Category M Fluid Services" and Chapter IX, "High Pressure Piping" shall not be used. Piping shall be designed in accordance with the methods and guidelines prescribed in Chapter II "Design." A 12.5% increase in the calculated wall thickness of pipe runs shall be added to allow for variations in mill fabrication tolerances. For each service, an evaluation shall be performed during preliminary design determining the amount of wall thickness that will be added to the calculated thickness to allow for corrosion.

Use of welded connections in high pressure systems is preferred to flanged connections. Welded connections limit the potential for leakage. For instruments and valves and connections to equipment, an evaluation shall be performed on a case-by-case basis to determine if (a) a connection must be welded for safety considerations, (b) a connection could be flanged for maintenance and access reasons, but welding could also be performed depending on the frequency of maintenance, (c) a flanged connection is required because of frequent access.

Estimated maximum flow velocities in piping systems are as follows:

- Waste piping—10 fps
- Water piping—10 fps
- LOX piping—10 fps
- GOX piping—25 fps
- Effluent piping—10 fps.

These velocities are guidelines that may be adjusted up or down depending on system specific design parameters. The primary requirement governing fluid velocity is to limit the settling of solids in the piping, and for the GOX system, to ensure gas velocity does not exceed recommended limits.

3.6.2 Construction Materials

Materials for piping shall be selected considering these design parameters:

- Stress generated in the material as a function of pressure
- Temperature, thermal fatigue, thermal stress, and thermal transients
- Resistance to corrosion, stress corrosion cracking, and pitting
- Severity of service application
- Mechanical fatigue and creep
- Constructability and weldability.

An analysis shall be performed to ensure that toughness, high pressure service, and high and low temperature are considered before determining which material shall be used for fabrication of piping.

ASTM certified mill test reports (CMTRs) shall be required for all metallic piping, fitting, and valve components (including bolts and nuts) in high pressure service (i.e., 900 psig and above). CMTRs shall conform to the requirements of the applicable ASTM standard. CMTRs for nonmetallic items, such as gaskets and valve packings, shall also be required for materials used in LOX and GOX service. No dual or multiple certification for ASTM standard materials shall be allowed (i.e., only one material type shall appear on any CMTR).

Asbestos or other hazardous materials shall not be used in the SCWO test bed construction materials.

3.6.3 Flanges and Fittings

Flanges for low pressure (less than 900 psig) systems shall conform to the requirements of ANSI B16.5, "Steel Pipe Flanges, Flanged Valves, and Fittings" and generally shall be weld neck, raised face, with flange facings specified depending on conditions of service.

Flanges for high pressure systems (900 psig and above) shall be Reflange hub and clamp type (or a similar manufacturer such as Graylok or Oteco). Material types and grades will be selected depending on service. Specific catalog and ordering information for each flange component (i.e., hub, clamp, seal, bolts, and nuts) shall be included in the design documents. Seal rings shall be provided for each Reflange-type connection and selected for resistance to corrosion depending on the intended service. Spare seal rings shall be specified on the drawings for service connections that will frequently be opened for inspection and maintenance. G-con sealrings shall be used for Reflange hub connections.

Bolting materials shall generally conform to ASTM A193 for bolts and ASTM A194 for nuts; however, during preliminary design, a detailed investigation shall be performed concerning material designation for high and low temperature systems.

Fittings shall generally consist of elbows, 45 degree elbows, 180 degree returns, weldolets, tees, caps, and reducers. Fittings shall be wrought, seamless, butt welded, sized to match pipe wall thickness, and generally manufactured to ANSI B16.9. Material and grade designations for fittings shall depend on the service conditions and shall be selected during the preliminary and final design process. There could be, depending on the size of the fitting and conditions of service, instances where standard ANSI fittings will not accommodate the high pressure and temperature ratings expected for certain systems. In this case, the requirements of ANSI B31.3, paragraph 304.7.2 shall apply allowing for the design, analysis, testing, and fabrication of special, high pressure fittings. A risk assessment shall be performed in accordance with the EG&G Idaho *Architectural Engineering Standards* for all nonstandard fittings.

3.6.4 Design and Analysis for Support and Flexibility

As specified in Part 5 of ANSI B31.3, piping shall be analyzed for stresses induced by seismic and thermal loading conditions. For seismic loading, an importance factor of 1.25 shall be used and the requirements for UBC Zone 2b. Additionally, stresses that could be created by dynamic loading in piping systems with two-phase flow shall be evaluated. Nonstandard piping components (not included in Appendix D of ANSI B31.3) that are included in the piping flexibility analysis must have flexibility and stress intensification factors based on experimental or theoretical analysis.

The arrangement and routing of pipe shall allow for sufficient flexibility and support under the design conditions specified above. Undue stress shall not be imparted to the piping, or equipment the piping is connected to, causing a breach of the system. If spring type supports are required, the use of overhead supports shall be limited and floor-mounted can supports used wherever possible.

3.6.5 Insulation Requirements

All piping, valves, fittings, instruments, vessels, equipment, other components on systems operating over 125°F, and the LOX system shall be insulated for personnel protection and heat retention. Insulation shall be designed with sufficient thickness to limit the surface temperature of the insulation to 125°F for personnel burn protection. Insulation thickness for required process heat retention shall be determined during the design. To the greatest extent practicable, insulation shall be fabricated for ease of installation and removal (it is anticipated that many of the SCWO piping and equipment components will be removed for reconfiguration of the test bed to accommodate placement of new reactor designs). An analysis of detailed insulation material and construction specification shall be conducted during preliminary design. The LOX transfer piping between the

storage tank and vaporizer shall be vacuum jacketed to minimize heat loss and condensation on the line. No asbestos shall be allowed for use as insulation.

3.6.6 Manual Valve Selection

Manually operated gate, globe, ball valves, and pressure relief and check valves shall be selected in accordance with service conditions as specified on the process and instrumentation diagrams. Manual valves shall conform to the requirements of ANSI B16.34, "Flanged and Butt Welding End Valves." Valve body and bonnet material shall be the same as materials specified for piping systems, although different materials may be used depending on specific conditions of service identified during the design. When critical to a particular service, allowable leak rates shall be specified, otherwise it shall be assumed that leakage allowable under ANSI guidelines is acceptable. When specifying manual valves, such factors as type of end connections (i.e., flanged or welded), flange facings, valve bonnet facings, type of hand operator, clearances for rising stems and removal of valve internals, shop testing, spare parts, material certifications, and cleaning requirements shall be considered. Valves for use in LOX service and high pressure and/or high pressure GOX service shall be fabricated from materials that are compatible with oxygen at the conditions of service specified. Pressure relief valves or rupture disk settings shall be specified on the Process and Instrumentation Diagrams (P&IDs). Position of check valves shall be considered when selecting this type of valve for installation in a vertical or horizontal application.

3.6.7 Welding

All welding for piping shall be performed in accordance with ANSI B31.3. It is mandatory that specified welding processes produce a smooth and clean weld that is less susceptible to "sugaring" during the welding process and limits the potential for pitting or irregularities at the weld surface that may promote corrosion. Pipe joints, fittings, and any other items to be welded shall be selected with respect to weldability. Positioning of joints and items to be welded shall be examined to ensure access to perform welding operations. End preparation of pipe, fittings, or other items to be welded shall be checked and specified to ensure compatibility. All personnel performing welding shall be qualified (per ANSI B31.3) to the procedure being used, and procedures shall be qualified in accordance with ANSI B31.3.

3.6.8 Special Piping Systems Design Considerations

Piping systems that will carry hazardous materials or wastes shall be designed in accordance with 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities." Generally, this guidance requires that piping used in the transfer of hazardous constituents be double contained and provided with a system for leak detection. For high pressure piping located in the north pit, the pit may act as the second point of containment. For piping systems located outside of the pit, double piping may be required. An evaluation shall be performed to determine the specific need and design approach for double-contained piping systems during the preliminary and final design.

For the design of piping systems and equipment components containing LOX and GOX, the following guidelines shall be followed: NASA Reference Publication 1113, "Design Guide for High Pressure Oxygen Systems," Military Specification 1246B, "Cleaning for Oxygen Systems, and Compressed Gas Association," and CGA-4.1, "Cleaning Equipment for Oxygen Service."

3.6.9 Inspection and Testing

All piping butt welds (shop and field) shall be examined by radiography in accordance with ANSI B31.3. When laying out and arranging the piping, placement of radiography equipment shall be considered to ensure that adequate space and access is allowed for visual field inspection. Weldolets and fillet welds shall be examined by means of liquid penetrant testing. All welds shall be visually inspected in accordance with ANSI B31.3.

Impact testing, special mill pressure testing (for heavy wall pipe), and other testing shall be specified as cited in ANSI B31.3 and applicable ASTM standards.

Piping shall be designed to accommodate field hydrotesting. Although for high pressure systems welded connections are preferred, the use of flanged connections shall be examined for blinds placement. In-line components, especially in LOX and GOX systems requiring special cleaning, may need fabricated spools to be installed during hydrotest. Provisions for low point drains and high point vents in each system shall be included in the design.

3.7 General Design Requirements for Equipment and In-line Components

3.7.1 Types of Equipment Used for SCWO Test Bed

Equipment shall be selected based on process requirements identified on the P&IDs. Equipment and components shall be securely fixed to a floor, wall, foundation, or other structure. Table 2 shows a list of the equipment anticipated for use on the SCWO test bed, function of equipment, and conditions of service.

3.7.2 In-line Components

Table 3 shows a listing of other in-line components that shall be used in the SCWO test bed.

3.7.3 Construction Materials

Materials for all equipment, machinery, and in-line components shall be selected based on the following criteria:

- Stress generated in the material as a function of pressure
- Temperature, thermal fatigue, thermal stress, and thermal transients
- Resistance to corrosion, stress corrosion cracking, and pitting
- Severity of service application
- Mechanical fatigue and creep.

Table 2. Equipment for the SCWO test bed.

Type of equipment	Function	Conditions of service (flow, temperature, and pressures shown are maximum design values)
Paddle mixer (for first waste mixing tank)	Waste and water mixing	Capable of mixing approximately 550 gal of water and 50 gal of waste constituents into a (nearly) homogeneous fluid in 15 minutes
Paddle mixer (for second waste mixing tank)	Waste and water mixing	Capable of mixing approximately 550 gal of water and 50 gal of waste constituents into a (nearly) homogeneous fluid in 15 minutes
Pump	Deionized water supply to waste mixing tanks	50 gpm, 100 psig, 60°F
Pump	Reactor cooling water feed	350 gph, 5,000 psig, 60°F,
Pump	Reactor mixing water feed	50 gph, 5,000 psig, 60°F
Pump	Waste feed to reactor	50 gph, 5,000 psig, 60°F, waste feed, 2,200 ppm maximum solids concentration, 100 microns maximum particle size
Pump	Metering pump to add supplemental fuel to waste feed	20 gph, 200 psig, 60°F
Pump	Metering pump to add neutralizer to cooling water	20 gph, 200 psig, 60°F
Pump	Pump liquid effluent from storage tank to evaporation pond	20 gpm, ambient to 100°F, 220 psig
Pump	Pump liquid effluent from storage tank to evaporator	20 gpm, ambient to 100°F, 220 psig
Heater	Heat wastestream to reactor	50 gph of waste, 5,000 psig, elevate temperature of fluid from 60 to 572°F
Heater	Heat supercritical water to reactor	50 gph of deionized water, 5,000 psig, elevate temperature of fluid from 60 to 1,250°F
Vaporizer	Convert LOX to GOX for feed to reactor, pressurize GOX	40 gph of LOX, 6,000 psig, -300 to 60°F
Evaporator	Boil off water from effluent	Sized to evaporate 400 gph

Table 3. In-line components used in the SCWO.

Type of component	Function	Conditions of service
Deionizer	Deionize feed water for SCWO system at a rate of 12 gph	12 gpm, 150 psig, 60°F. Deionizer columns are existing equipment at WRRTF and shall be refurbished for service (work to be performed by others)
Cyclone separator	Separate gas and liquids from first stage separator gas	1 to 30 ACFH, 250 psig, remove a maximum of 40 ppm solids
Orifice plates	Lower pressure of gas from first stage separation vessel	Reduce pressure of gas from first stage separator from a maximum of 5,000 psig to a minimum of 2,000 psig
Orifice plates	Lower pressure of liquid from first stage separation vessel to second stage separation vessel	Reduce pressure of liquid from first stage separator from a maximum of 5,000 psig to a minimum of 2,000 psig
Orifice plate	Reduce pressure of gas from cyclone separator	Reduce pressure of gas from 250 psig to 15 psig
Liquid effluent filters	Final filters to remove solids from effluent before entering evaporator	Remove 98%+ of suspended solids in effluent (remaining 2% will go to evaporator pond or evaporator)
Gas filters	Remove hazardous constituents from gas before release to atmosphere	Five filters sized for 17,000 hours of service under normal operating conditions; 3 hours of service for upset condition
Resin bed	Remove mercury from liquid effluent	One resin bed sized for 250 hours of operation; used only with effluent containing mercury
Heat exchanger	Cool effluent from second stage separator, remove gas	400 gph, 500 psig, cool effluent from 572°F to 80°F

3.7.4 Equipment Control

All pumps and the LOX/GOX vaporizer shall be designed for operation from the control room. Manual control of equipment may be necessary, but only to the extent it is required for testing, maintaining, or checking the equipment. Manual control of the equipment shall not be allowed at times when the SCWO test bed is operating. In addition to control of equipment, other equipment functions such as lubricant levels, temperature, and other indications of machine health shall be considered and specified for remote indication at the time the equipment is selected.

The control system shall provide continuous and on/off control signals for machinery control. Continuous control shall be provided by 4 to 20 mA current loops, and on/off control shall be provided by switched digital outputs capable of switching 60 Vdc or 120 Vac at 3 Amps.

All machinery protection (e.g., motor overcurrent protection) shall be provided by dedicated local controllers and not by the control system. The control system shall only provide signals to start, stop, and

control. Machinery control system overrides shall be provided when failure of the control system may cause harm to personnel or damage to equipment. The override controls shall be located in the control room as a minimum.

3.8 General Design Requirements for Instrumentation and Data Acquisition

The test bed data acquisition and control systems include all components and systems involved with the sensing, acquisition, storage, display, and control of process parameters. Final control elements such as control valves are not included in this definition. The test bed data acquisition and control system is divided into two separate systems: data acquisition system and control system for requirements definition only. The functionality of both may be combined into one system if all requirements are met.

3.8.1 Control System

The control system shall consist of the equipment needed for operations personnel to remotely monitor and control the test bed from the control room. The following requirements are considered necessary to meet this function:

- **Input/Output**—The measurement and control points are shown on Figures 3 through 11 (see Section 4). Table 4 summarizes the minimum required control system input/output (I/O) numbers and characteristics for interface to the test bed. It is not necessary to provide spare channel electronics initially, but the system shall have the capability to be expanded to the required number of spare channels at a later date.
- **Proportional Integral Derivative Control**—Proportional integral derivative control blocks shall be supplied to implement closed loop control. The number of proportional integral derivative control loops supported by the control system shall be equal to the sum of the required analog and digital outputs. Proportional integral derivative control using digital outputs shall support time modulation. Process variable inputs to proportional integral derivative control loops shall be derived from any analog input. Proportional integral derivative set points shall come from operator entry or analog inputs.
- **Alarms**—Audio and visual alarms shall be provided to alert operations personnel of the state of the process status. High and low alarms shall be implemented. Alarm inputs shall be derived from analog or digital inputs. Alarm status may be displayed on the control console CRTs.
- **Displays**—All digital and analog input and output monitoring or controlling process parameters are required to be presented to the operator using trend displays. A minimum of four process parameters are required to be trended at the operator's console at one time. The trend period should be operator selectable from minutes to at least 1 hour. Instantaneous displays may be provided to augment the trend displays.

Table 4. Control system I/O channel requirements.

	Quantity	Spares	Specifications
High-level ^a analog input	48	16	Range: $\pm 1.0, 5.0, 10.0$ Vdc Resolution: $\pm 0.025\%$ Accuracy: $\pm 0.1\%$ Sample Rate: 10/sec/channel
Low-level analog input	32	16	Range: $\pm 10.0, 50.0$ mVdc Resolution: $\pm 0.025\%$ Accuracy: $\pm 0.1\%$ Sample Rate: 1/sec/channel CMRR ^b : 60 dB at 60 Hz
High-level digital input	24	8	Range: 90 to 140 Vrms (ac/dc)
Low-level digital input	24	8	Range: 4 to 32 Vdc
Analog output	16	8	Range: 4 to 20 mA Resolution: $\pm 0.025\%$ Accuracy: $\pm 0.1\%$
High-level digital output	24	8	Range: 12 to 140 Vac at 3 Amps
Low-level digital output	24	8	Range: 3 to 60 Vdc at 3 Amps
Frequency input	0	4	Range: 0 to 10 kHz
Frequency output	0	4	Range: 0 to 10 kHz

a. Current loop inputs shall be handled with loop resistors.

b. Common Mode Rejection Ratio.

- Calibration—Analog input calibration shall be performed by inserting signals on each input before any control system signal conditioning equipment. Signal conditioning equipment as defined here only includes equipment associated with the control system. This does not include signal conditioning equipment associated with process instrumentation. Removal of field wiring from terminal boards is not acceptable to insert calibration signals. Removal of mass termination connectors at the control system and connection to a calibration standard is acceptable.

Analog output calibration shall be performed by measuring levels on each output after any control system signal conditioning equipment. Removal of field wiring from terminal boards is not acceptable to measure output levels. Removal of mass termination connectors at the control system and connection to calibration equipment is acceptable.

3.8.2 Acquisition System

The acquisition system shall consist of the equipment needed for operations personnel to remotely monitor the test bed from the control room. The following requirements are needed to meet this function:

- **Inputs**—The measurement points are shown on Figures 3 to 11 (see Section 4). Table 5 summarizes the minimum required acquisition system input numbers and characteristics for interface to the test bed.
- **Data Archiving**—All digital and analog I/O monitoring process parameters shall have the capability to be archived. The data shall be archived at an operator-selected archive rate. The archive period shall be at least 24 hours for all I/O without downloading. The archived data shall be downloaded to a media compatible with an IBM PC. All archived data shall be time tagged to within 10 seconds of the occurrence of the process parameter.
- **Displays**—All archived digital and analog I/O monitoring process parameters shall be presented to the operator using trend displays.
- **Calibration**—Analog input calibration shall be performed by inserting signals on each input before any acquisition system signal conditioning equipment. Signal conditioning equipment as defined here only includes equipment associated with the acquisition system. This does not include signal conditioning equipment associated with process instrumentation. Removal of field wiring from terminal boards is not acceptable to insert calibration signals. Removal of mass termination connectors at the control system and connection to a calibration standard is acceptable.

3.8.3 Control and Acquisition System Configuration

The control and acquisition system shall consist of transducers, signal interface electronics, display systems, actuators, and laboratory analysis equipment. Low energy test bed systems may be located abovegrade, while high energy systems shall be located belowgrade in the north pit.

The signal interface electronics shall be next to the test bed at a central location to minimize cable length and maintain a reasonable distance from high energy electrical systems to reduce the effects of Electromagnetic Interference. The electronics should also be located outside the Semi-Scale pit to avoid entering the pit for calibration and maintenance.

The operator's control console shall be located in the SAW control room. The control console shall consist of the control and acquisition system displays and any controls required to operate the test bed. The control console shall also include all shutdown and emergency controls required to override the test bed's normal operation of the control system.

3.8.4 Actuator Interface

The following are interface requirements for actuators and control system elements.

Table 5. Acquisition system input channel requirements.

Channel type	Quantity	Spares	Specifications
High-level ^a analog input	48	16	Range: $\pm 1.0, 5.0, 10.0$ Vdc Resolution: $\pm 0.025\%$ Accuracy: $\pm 0.1\%$ Sample Rate: 1/sec/channel
Low-level analog input	32	16	Range: $\pm 10.0, 50.0$ mVdc Resolution: $\pm 0.025\%$ Accuracy: $\pm 0.1\%$ Sample Rate: 1/sec/channel CMRR ^b : 60 dB at 60 Hz
High-level digital input	32	8	Range: 90 to 40 Vrms (ac/dc)
Low-level digital input	32	8	Range: 4 to 32 Vdc
Frequency input	0	4	Range: 0 to 10 kHz

a. Current loop inputs shall be handled with loop resistors.

b. Common Mode Rejection Ratio.

- Control Valves—The control system shall provide 4 to 20 mA current loop signals to position all control valves. The current loops shall have overcurrent protection.
- Noncontrol Valves—The control system shall provide switched 24 Vdc at 3 Amp control signals to control all on/off isolation valves. The control signal may also control pilot valves that shall supply plant air to valve actuators. The 24 Vdc outputs shall have overcurrent protection.
- Heater Control—The control system shall provide 4 to 20 mA current loop signals or time modulated on/off signals to heater controllers. Current loops shall have overcurrent protection.

The control system shall provide switched 24 Vdc at 3 Amp control signals to control all on/off heater controllers. The control signal may be used to control high power switching devices. The 24 Vdc outputs shall have overcurrent protection.

- Motors—The control system shall provide switched 24 Vdc at 3 Amp control signals to control all on/off motors. The control signal may be used to activate motor controllers. The 24 Vdc outputs shall have overcurrent protection.

3.8.5 Grounding/Shielding

Grounding and shielding requirements include the following:

- All control system components shall be properly grounded and shielded for personnel protection.
- The control system signal interface cabinets and I/O electronics shall be permanently grounded to the test bed metallic superstructure. The super structure shall be permanently grounded to the facility ground.
- The control room structure and utility power shall be grounded to the facility ground.
- Isolation shall be provided for all signal wires that link the interface cabinets located on the test bed to the control room.
- All single ended analog inputs shall require transducers that are electrically isolated from the test bed metallic superstructure.
- All analog inputs and outputs shall be wired to the control and acquisition system using twisted shielded pairs.
- All on/off control signal wiring shall use twisted pairs as a minimum.

3.8.6 Temperature

All temperature measurements shall be made with grounded type K thermocouples. Signal wires shall be contained in a high-temperature flexible overbraid or sheath that can withstand up to 1,800°F. The overbraid shall be long enough to make the transition from the high-temperature environment to ambient temperature. The signal wire shall be terminated with a color-coded connector that can withstand a 400°F ambient temperature. Thermocouple extension wire shall be used to connect the thermocouple to the data acquisition and control system. The extension wire shall be shielded and have an insulation temperature specification of at least 200°F.

3.8.7 Chemical Analysis Instrumentation

The *Supercritical Water Oxidation Hazardous Waste Pilot Plant Data Quality Plan*⁶ provides sampling and analysis methodology and approach. Sample ports are identified for obtaining chemical composition and concentration analysis of gas, liquid, and solid samples. All gas analysis shall be on-line, continuous, on demand, and performed by automatic gas sampling and analysis systems. The data shall be monitored and recorded by the plant data acquisition system during each test run. All liquid and solids analysis shall be performed off-line. Samples shall be taken by grab sample methods and analyzed by either INEL laboratories or by offsite certified laboratories. The data shall be entered into a data base for correlation with on-line data acquired during each test run by the data acquisition system. All liquid and solid analysis requiring a turnaround time less than can be obtained from an INEL or subcontract laboratory shall be performed by on-line analysis equipment or analysis equipment located at the test bed laboratory.

The data obtained from the chemical analysis equipment shall be used to determine test bed performance as well as environmental analyses of effluent prior to release or disposal. All test bed chemical analysis equipment shall be located so it will not pose a threat to the environment and can be maintained safely during test bed operation.

The continuous on-line sampling and analysis systems may be contracted to outside vendors. This may include any or all portions associated with pressure letdown, temperature reduction, sample preparation, sample flow control, sample line purging, and analysis equipment.

- **Deionized Water Feed Line**—The deionized water feed line shall be monitored for conductivity as an indication of water quality. The clean water feeding the SCWO test bed shall be of high quality so that the conductivity can be maintained above 10 megohm for each test run. Water conductivity data shall be continuously acquired with the process data by the data acquisition system during each test run. Water conductivity shall be measured with an in-line instrument permanently located near the outlet of the deionized water storage tanks (prior to where the feed water line branches). The conductivity will be continuously monitored by the in-line instrument and interfaced with the control and data acquisition system. A condition of low conductivity shall be alarmed at the test bed control station.

A tee and valve shall be located near the deionized water storage tank (before the line branches). This location will provide the capability to obtain samples manually whenever desired. Samples shall be obtained by opening the valve and flowing water into a collection bottle. The valve shall be selected so that the flow of water is restricted to a low volume to prevent uncontrolled discharge.

- **Waste Feed Line**—The waste contained in the waste mixing tanks 1 and 2 shall be chemically analyzed prior to use in the test bed. A tee and valve shall be located on the waste feed lines from each waste mixing tank. As with the deionized water, the samples shall be obtained manually by opening a valve and flowing liquid into a collection bottle.

Another tee and valve shall be located downstream of where the supplemental fuel line enters the waste feed line, and another tee and valve shall be located downstream of where the neutralizing agent is injected into the cooling water line. Liquid samples shall be obtained manually from each of these locations.

Reactor input waste composition and concentration shall be derived from the known water, waste, fuel, neutralizer composition, and associated flow rates.

- **First Stage Separator Gas (High Pressure)**—The first stage separator gas upstream of the high pressure orifice plate shall be continuously analyzed for gas concentration and composition. The data shall be acquired by the data acquisition system during each test run. The gas output shall be monitored for the compounds identified in Table 6.

A sample port shall be included upstream of the orifice. Tubing will be routed from this point to a gas chromatograph (or similar device to be used for the on-line analysis of gas samples). Small diameter tubing is required because the gas analyzer requires only a few milliliters of a sample to perform the analysis. A remote-operated control valve shall be used to control the flow of gas to analyzer. A method to purge the line between the control valve and the analyzer after each use shall be provided. Pressure relief in the line for an upset condition shall also be provided. The gas analyzer will be provided with the capability to control the flow and reduce the pressure of the gas to the instrument.

Table 6. Gas monitoring output.

Compound	Range (v/v) ^a	Uncertainty
CO	0 to 0.1%	± 5%
CO ₂	0 to 100%	± 5%
O ₂	0 to 100%	± 5%
H ₂ O	0 to 10%	± 5%
N ₂	0 to 1%	± 5%
Cl	0 to 0.1%	± 5%
NOX	0 to 0.1%	± 5%
Hg	TBD	TBD

a. v/v = volume/volume

- **First Stage Separator Gas (Low Pressure)**—The first stage separator gas on the downstream side of the high pressure orifice plate shall be analyzed for gas and solid particulate^a concentration and composition using the same requirements as stated in Table 6. A sample line shall be routed from just past the orifice low pressure side to the gas analyzer. The same requirements will be observed as stated for the tubing run for the first stage separator, gas high pressure side.
- **First Stage Separator, Gas Line Cyclone, Liquid/Solid Output**—The first stage separator, gas line cyclone separator, liquid/solid output shall be analyzed for solid particulate concentration and composition using the same requirements as stated in Table 6. A tee and valve shall be provided at the base of the cyclone separator. A manual sample shall be periodically obtained from this location when the system is not operational.
- **First Stage Separator, Gas Emissions Line**—The first stage separator, gas emissions line shall be analyzed for gas concentration and composition using the same gas analysis requirements as stated in Table 6. A tee shall be installed upstream of the gas inlet line from where the second stage separator connects with the first stage separator gas line to the filters. Tubing will be routed to the gas analyzer so continuous samples may be obtained (the same requirements will be observed as stated for the tubing run for the first stage separator, gas high pressure side).
- **First Stage Separator Liquid Effluent**—The first stage separator liquid effluent shall be continuously monitored for conductivity, turbidity, and pH^b as defined in Table 7 and for total organic carbon (TOC) as defined in Table 8. The data shall be recorded by the data acquisition system during each test run. Conductivity, turbidity, and pH changes indicate a corrosion rate change that will require more frequent sampling of the liquid output for chemical compound composition and concentration. Instrumentation capable of performing continuous on-line

a. Solid particulate measurement feasibility shall be evaluated in the SCWO test bed sampling and analysis plan.

b. Conductivity, turbidity, and pH measurement feasibility shall be evaluated in the SCWO test bed sampling and analysis plan.

monitoring for conductivity, turbidity, pH, and TOC will be installed just after the liquid effluent is discharged from the first stage separator.

In addition, the first separator liquid effluent shall be periodically sampled and analyzed off-line for chemical compound concentration and composition. The sampling rate shall be based on test run requirements and evaluation of the conductivity, turbidity, pH, and TOC measurements as defined in test and sampling and analysis plans. Sample ports shall be located upstream of the first stage separator, liquid high pressure orifice. Tubing will be routed to a series of sample bombs, which will be located in a remote area (i.e., the sample bombs will not be accessible during operation of the test bed). The sample bomb system will be designed so that the liquid sample may be obtained in the bomb. The bomb is then cooled and the pressure let down. The bomb is retrieved for analysis, and a new bomb is inserted to acquire a new sample. The liquid effluent shall be monitored for the compounds identified in Table 8. Other requirements for location, configuration, number, remote operation, and interface with the control system shall be determined during the detailed design.

- **Second Stage Separator, Gas Emission Line**—The second stage separator, gas emission line shall be analyzed for gas concentration and composition using the same gas analysis requirements as stated in Table 6. A tee shall be installed on the second stage separator, gas emission line before the line connects with the first stage separator gas emission line. From the tee, tubing will be routed to the gas analyzer so on-line, on demand samples may be obtained (the same requirements will be observed as stated for tubing run for the first stage separator, gas high pressure side).
- **Solids Filter**—The solids filter located downstream of the second stage separator liquid line shall be analyzed for solid particulate concentration and composition using the same requirements as stated in Table 6. The filter shall be designed so that the filter element is removable during operation, and solid materials may be collected for laboratory analysis.
- **Solids Filter Liquid**—Liquid on the downstream side of the solids filter shall be analyzed using the same liquid analysis requirements for the liquid orifice plate input as stated in Table 8. A tee and valve shall be provided so liquid samples may be manually obtained.
- **Filtered Gas Emissions**—Filtered gas shall be analyzed for gas concentration and composition just prior to release to the atmosphere. The data shall be acquired by the data acquisition system during each test run. The filtered gas shall be monitored for the compounds identified in Table 9. A tee shall be installed after the gas is filtered and before the gas is emitted to the atmosphere. Tubing shall be run to the gas analyzer from the tee so continuous samples may be obtained (the

Table 7. Output monitored for turbidity and conductivity.

Measurement	Range	Uncertainty
Turbidity	TBD	TBD
Conductivity	TBD	TBD
pH	1 to 14	5%

Table 8. Compounds monitored in liquid output.

Compound	Range	Uncertainty
TOC	0 to 0.5%	5%
Total carbons	TBD	TBD
Total organic halides	0 to 100 ppm	5%
Total halides	TBD	TBD
pH	1 to 14	5%
Total solids	0 to 20%	5%
NOX	TBD	TBD
Metals (from feed and corrosion by products)	TBD	TBD
Specified organic compounds	TBD	TBD
SO ₄	TBD	TBD
PO ₄	TBD	TBD

same requirements will be observed as stated for tubing run for the first stage separator, gas high pressure side).

- **Effluent Storage Tanks**—The liquid in the effluent storage tanks shall be analyzed to determine if concentrations are above or below RCRA established limits for hazardous wastes. If below established limits, the effluent will be discharged to the WRRTF evaporation pond. If the effluent is determined to be hazardous, it will be evaporated and the solid/sludge residue collected, handled, and disposed as a hazardous waste. Sample(s) shall be taken from the effluent storage tanks so that a true representation of the constituents in the liquid is obtained.
- Equipment capable of analyzing gas samples on a continuous basis and at a minimum, analyzing for various characteristics of constituents mentioned in Tables 6 and 9 shall be provided. The analyzing equipment shall be located and operated remotely. Gas sample lines shall be interfaced with the analyzer. Technical specifications for the gas analyzing equipment shall be determined during the detailed design.

3.8.8 Remote Control of Process

The control system shall provide for remote control and monitoring of all test bed systems located in the north pit from the control room. Functions are those required for startup, normal and emergency operation, and shutdown of the test bed. Access to the north pit shall not be allowed while the test bed is at operating pressure.

3.8.9 Calibration

Control and acquisition system components may be calibrated individually and off-line. The components may then be reinstalled in the test bed and the system verified for proper operation. The data acquisition system shall require periodic end-to-end calibration checks to verify system performance. The checks should start as close to the process parameter as possible and be verified to the output device.

Table 9. Filtered gas compounds and monitoring requirements.

Compound	Range	Uncertainty
CO	TBD	TBD
CO ₂	TBD	TBD
O ₂	TBD	TBD
H ₂ O	TBD	TBD
HCl ^a	TBD	TBD
NOX	TBD	TBD
Hg	TBD	TBD
TOC	TBD	TBD
Hydrocarbons	TBD	TBD

a. Hydrochloric acid

For instance, a pressure measurement should require inserting a calibrated pressure standard on the input to the pressure transducer and verified to the control system console and mass storage media.

3.8.10 Test Bed Control Room

The WRRTF SAW control room shall be used as the test bed control room. The test bed operator's control console shall be located in this control room and shall consist of the following items:

- An 8-ft long table (provided by the program) located against the south wall beneath the window. The operator should be able to look out the window and view the north pit.
- Control and acquisition system CRTs and keyboards located on the table.
- Console located to the left of table to house the manual override controls.
- Existing lighting and air conditioning shall be left intact for the test bed control room.

All wiring, controls, and cabinets not related to the test bed shall be removed from the SAW control room. Affected systems shall be secured prior to removal. Wiring shall be removed from the control room operating floor cabinets to the north pit. Controls shall be removed from the affected cabinets and the cabinets removed from the control room. The cabinets located below the control room and the wire trays routed from the control room to the north pit shall not be removed.

3.8.11 Test Bed Chemistry Laboratory

Requirements for off-line chemical analysis equipment and associated requirements for test bed chemistry laboratory support cannot be determined at this time. The off-line chemical analysis equipment shall be specified and obtained by the project. The laboratory will require 400 ft² of space and be equipped with a fume hood, fume hood gas filter, air, water, and holding tank for liquid effluent. The laboratory design shall accommodate disposal of all analysis effluent. The laboratory shall be provided by the program.

3.9 General Design Requirements for Electrical Power and Lighting

3.9.1 Existing WRRTF Equipment

Any modifications or upgrade work required for the existing electrical equipment at WRRTF to render it suitable for the SCWO project is beyond the scope of the test bed design and shall be performed by others.

There appears to be adequate power available at Building 646. Existing equipment includes dc power supplies; water-cooled, inductive-capacitive filters; and buswork. The buswork provides many connection points in the north pit. The existing connections that feed equipment from the previous project located in the north pit need to be removed and the buswork enclosed to prepare for SCWO test bed connections.

There are several motor control centers (MCCs) that have many unused breakers. These breakers were formerly used to supply process support equipment and should be easily converted for the same purpose in the SCWO project. The MCCs are generally old but in good shape. There are three MCCs located together in one room. These MCCs should not be used because there is insufficient clearance between the front of the MCCs, which constitutes a NEC violation, and a hazard to maintenance/construction personnel.

3.9.2 New Equipment Required

Currently, there is no new major electrical equipment required to directly support the test bed. New power cabling and control leads from the existing MCCs to the loads in the pit and control room and conduit/cable tray to run these leads shall be required. Adequate 120 and 240 V power receptacles shall be provided in and around the pit to support tools, temporary lighting, test equipment, and related activities. All work shall be performed in accordance with the NESC and NEC, and the materials shall meet the requirements of UL and NEMA.

3.9.3 Emergency Power Requirements

Emergency power shall be supplied to the SCWO test bed to provide for personnel protection and safe shutdown of equipment in the event of a power failure. Personnel protection includes emergency lighting, and safe shutdown includes operation of equipment, valves, and instruments to terminate the process, reduce pressure, control flow and heat generation, and ensure containment of all fluids, gases, and solids. An emergency power source shall be located within the WRRTF and selected so that it does not require any special maintenance, ventilation, or operation. Operation shall be designed so that when the normal supply of power to the test bed is interrupted, emergency power is instantaneously available.

3.9.4 Lighting Requirements

Lighting shall be designed and installed in the north pit. A minimum illumination of 60 ft-candles/ft² shall be provided. New emergency exit lighting is also required in the pit (30 ft-candles/ft²). The emergency exit could use normal fixtures to provide lighting, but it should also be equipped with self-contained battery packs for short-term operation, or emergency lights could be powered from the emergency power supply system. The control room shall require typical illumination levels of about 100 ft-candles provided by standard fluorescent

fixtures. Personnel eating areas and passageways, shop areas, and storage areas shall be furnished with 60 ft-candles of illumination.

3.9.5 Heat Tracing

Adequate heat tracing and controls shall be provided to prevent freezing of the liquids contained in piping and equipment located outside of WRRTF Building 656. Systems and individual components shall be evaluated to determine the need for heat tracing. The control system for heat tracing shall be an automatic thermostat that can be set to activate at a preset, minimum, ambient air temperature and automatically shut off when the ambient temperature is warm enough to ensure no freezing will occur. The system shall be designed with a manual override to turn the heat tracing on and off. The heat tracing controls shall also be interfaced with the test bed control station to provide an on/off indication. Failure of the heat tracing system shall be alarmed at the test bed control station.

3.9.6 Video

A color video camera system shall be provided to allow remote viewing of the portion of the test bed located in the north pit and equipment located outdoors. The cameras shall include pan, tilt, focus, and zoom features. Adequate lighting shall be provided as a part of the video system. Color camera monitors and camera controls shall be located in the control room.

3.9.7 Communications

It is assumed that voice communications between personnel working in the north pit and personnel outside of the pit will be accomplished by radio (provided by the program). Any other communication features including phones, intercom, facility alarms, and personal address, if required, shall be provided by the program.

3.10 General Design Requirements for Structural and Concrete

3.10.1 Structural

Design, fabrication, and installation of structural steel shall be done in accordance with the AISC. Structural welding shall be performed in accordance with the AWS Structural Welding Code D1.1. Design of handrails, ladders, stairs, and toe plates shall be in accordance with CFR 29 Chapter XVII Part 1910, "Occupation Safety and Health Standards." Seismic design (for both structural and concrete) shall be performed in accordance with DOE-STD-1020-92, "Design and Evaluation Criteria for Department of Energy Facilities." The test bed is located in UBC Zone 2b, and an importance factor of 1.25 shall be used based on a low preliminary hazards classification.

A structural steel platform shall be provided about the mid-way elevation in the north pit to locate equipment and access the reactor, and provide storage and a work area for personnel. The platform shall include the design of all necessary stairs, ladders, and handrails. The platform shall be designed for 150-lb/ft² loading. All floor grating shall be galvanized. Structural steel shall receive a prime coat of paint. At a minimum, a protective cover shall be required over the GOX accumulators to prevent damage to the vessels from objects that could be dropped from the overhead crane in Building 646. Depending on the results of the safety analysis, a structural steel cover could be required over the entire top of the pit, but this will not be determined until the safety analysis is completed.

Other structural work will include design of miscellaneous supports for piping and mounting plates to structural members for small equipment items.

3.10.2 Concrete

Concrete foundations and pads shall be designed and constructed in accordance with applicable sections of the American Concrete Institute code and standards. Foundations shall be required for equipment located outside of Building 646. Indoor equipment will generally be mounted to existing concrete slabs and shall be evaluated for seismic loading. Areas that store or mix hazardous materials and wastes shall be contained in accordance with 40 CFR, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities." Any liners or coatings required inside of containment areas shall be identified.

3.11 General Design Requirements for Tubing

Tubing shall be provided for the sampling, purge, instrument air, and miscellaneous process systems as identified on the P&IDs. Tubing materials shall be selected for the intended process service and conditions of pressure, temperature, flow rate, corrosion, and constructability. Field tubing shall be routed and fabricated as required by applicable standards of the Instrument Society of America. To the extent practicable, tubing and fittings shall be of one material type and from one manufacturer (i.e., use one fitting type throughout the test bed). Tubing design includes all mounting and support, selecting fittings and valves, determining if the tubing needs to be insulated for heat retention and personnel protection, and defining the interface with piping and equipment.

The sampling system consists of tubing that runs from various sampling ports on the test bed (identified in Section 3.8.7, "Chemical Analysis Documentation" and shown on the P&IDs) to the gas analyzer. Each sample line will be evaluated for pressure let down, flow control, interface with the control system, purging, a method of flow through, pressure relief, and a method of sample disposal. Sample bombs will also be required for obtaining in process liquid samples. The sample bomb manifold should be located near the first stage separator. The sample bombs will be filled remotely. The number of sample bombs, configuration of the manifold, and how the bombs will be removed and replaced are design issues that need to be investigated.

The nitrogen purge system shall be provided to the locations shown on the P&IDs. Design of the system includes location of the nitrogen bottles, all valves, flex hoses, and defining connection fittings on the piping systems. Special filtering is required for nitrogen used to purge the oxygen system. Refer to NASA Reference Publication 1113, "Design Guide for High Pressure Oxygen Systems" for specific information on filtering and cleanliness requirements.

An instrument air header fabricated from tubing may be required depending on the selection of instrumentation and control valves. There may be other miscellaneous process lines that will be fabricated from tubing, and these will be identified on the P&IDs.

4. SPECIFIC REQUIREMENTS

For a schematic representation of the following systems, refer to the P&IDs shown on Figures 3 through 11.

4.1 Deionized Water System

The existing deionized water system at WRRTF shall be used to supply water to the SCWO process. The existing system consists of a resin column, acid and base tanks, polishing columns, and storage tanks. The process requires a maximum total of 400 gph of deionized water. The 400 gph is derived from the maximum amount of waste feed mixing water (i.e., 50 gph), plus the maximum amount of cooling water needed in the reactor and first stage separator to cool the effluent (i.e., 350 gph). For a 100-hour test, a total of 40,000 gal of water will be required. To ensure an adequate supply of water, it will be necessary to first store a sufficient quantity of water for startup and initial operation of the plant, and second, to replenish the storage system periodically during operation, providing a continuous supply of water. A total storage capacity of 5,000 gal and the ability to produce deionized water at a rate of 12 gpm for 8 hours to refill the storage system is required (the deionized water system must recharge for 12 hours after 8 hours of use). There are three existing tanks that can be used for storage, one 3,000 gal and two 1,000 gal. It is assumed that at the start of a test the storage tanks and waste mixing tanks (about 1,000-gal capacity) will be filled. A small (20 to 25-gpm) pump will be needed to transfer water from the small storage tanks to the large storage tank. Water to the process shall always be fed from the large storage tank. Control of the deionized water system will be performed manually.

4.2 Low Pressure Water Supply and Waste Mixing

Deionized water shall be supplied to two mixing tanks. The tanks shall be sized to support one 10-hour test without refilling. They shall also be used to support tests of longer duration (up to 100 hours) if one tank is used to supply waste to the reactor, and the other is filled and waste constituents and water are mixed. Only one tank shall be used at a time to supply waste to the reactor. A pump shall be provided after the 3,000-gal deionized water tank to supply water to the mixing tanks. The pump shall be capable of filling each tank in 10 minutes. A check valve shall be provided downstream of the pump to prevent back flow through the pump.

Waste constituents will be added manually to each tank. A nozzle shall be provided so liquid waste constituents may be pumped into the tank from a 55-gal drum, or similar container, using a small metering pump. Solid waste constituents will be added to the tank from a chemical addition funnel located on top of the tank. The tanks will be covered and only subjected to atmospheric pressure. A small gas vent nozzle and line shall be provided at the top of the tank. The vent line shall be routed to a gas collection manifold and either vented to atmosphere, or filtered and then vented. The vent line serves several purposes. Excess moisture and gas that may be generated during the mixing process are vented outdoors, and excess pressure will not build up in the tank. A small fan will be used to create a small negative pressure in each tank. Temperature indicators shall be provided on each tank.

Figure 3. P&ID No. P-3, support systems.

Figure 4. P&ID No. P-4, LOX system.

Figure 5. P&ID No. P-5, waste mixing.

Figure 6. P&ID No. P-6, deionized water system.

The diagram illustrates the Reactor Fuel System (RFS) with the following components and connections:

- Reactor:** A central component with a dashed outline, connected to the fuel system.
- Fuel Elements:** Labeled HTR-4 and HTR-5, each with a resistance symbol and a note "ASB TO 820°F".
- Fuel Handling System:** Includes a "FROM COOLING WATER SYS. SEE SHT P-8" inlet, a "HEATER POWER" block, and a "FROM PLUG SYSTEM SEE SHT P-8" inlet.
- Piping and Valves:** Various pipes with flow directions and valves labeled HV-406, HV-407, and HV-408.
- Instrumentation:** Includes pressure gauges (P-3, P-4), flow meters (FV-401, FV-402), and temperature sensors (T-1, T-2, T-3, T-4, T-5, T-6, T-7, T-8, T-9, T-10, T-11, T-12, T-13, T-14, T-15, T-16, T-17, T-18, T-19, T-20, T-21, T-22, T-23, T-24, T-25, T-26, T-27, T-28, T-29, T-30, T-31, T-32, T-33, T-34, T-35, T-36, T-37, T-38, T-39, T-40, T-41, T-42, T-43, T-44, T-45, T-46, T-47, T-48, T-49, T-50, T-51, T-52, T-53, T-54, T-55, T-56, T-57, T-58, T-59, T-60, T-61, T-62, T-63, T-64, T-65, T-66, T-67, T-68, T-69, T-70, T-71, T-72, T-73, T-74, T-75, T-76, T-77, T-78, T-79, T-80, T-81, T-82, T-83, T-84, T-85, T-86, T-87, T-88, T-89, T-90, T-91, T-92, T-93, T-94, T-95, T-96, T-97, T-98, T-99, T-100, T-101, T-102, T-103, T-104, T-105, T-106, T-107, T-108, T-109, T-110, T-111, T-112, T-113, T-114, T-115, T-116, T-117, T-118, T-119, T-120, T-121, T-122, T-123, T-124, T-125, T-126, T-127, T-128, T-129, T-130, T-131, T-132, T-133, T-134, T-135, T-136, T-137, T-138, T-139, T-140, T-141, T-142, T-143, T-144, T-145, T-146, T-147, T-148, T-149, T-150, T-151, T-152, T-153, T-154, T-155, T-156, T-157, T-158, T-159, T-160, T-161, T-162, T-163, T-164, T-165, T-166, T-167, T-168, T-169, T-170, T-171, T-172, T-173, T-174, T-175, T-176, T-177, T-178, T-179, T-180, T-181, T-182, T-183, T-184, T-185, T-186, T-187, T-188, T-189, T-190, T-191, T-192, T-193, T-194, T-195, T-196, T-197, T-198, T-199, T-200, T-201, T-202, T-203, T-204, T-205, T-206, T-207, T-208, T-209, T-210, T-211, T-212, T-213, T-214, T-215, T-216, T-217, T-218, T-219, T-220, T-221, T-222, T-223, T-224, T-225, T-226, T-227, T-228, T-229, T-230, T-231, T-232, T-233, T-234, T-235, T-236, T-237, T-238, T-239, T-240, T-241, T-242, T-243, T-244, T-245, T-246, T-247, T-248, T-249, T-250, T-251, T-252, T-253, T-254, T-255, T-256, T-257, T-258, T-259, T-260, T-261, T-262, T-263, T-264, T-265, T-266, T-267, T-268, T-269, T-270, T-271, T-272, T-273, T-274, T-275, T-276, T-277, T-278, T-279, T-280, T-281, T-282, T-283, T-284, T-285, T-286, T-287, T-288, T-289, T-290, T-291, T-292, T-293, T-294, T-295, T-296, T-297, T-298, T-299, T-300, T-301, T-302, T-303, T-304, T-305, T-306, T-307, T-308, T-309, T-310, T-311, T-312, T-313, T-314, T-315, T-316, T-317, T-318, T-319, T-320, T-321, T-322, T-323, T-324, T-325, T-326, T-327, T-328, T-329, T-330, T-331, T-332, T-333, T-334, T-335, T-336, T-337, T-338, T-339, T-340, T-341, T-342, T-343, T-344, T-345, T-346, T-347, T-348, T-349, T-350, T-351, T-352, T-353, T-354, T-355, T-356, T-357, T-358, T-359, T-360, T-361, T-362, T-363, T-364, T-365, T-366, T-367, T-368, T-369, T-370, T-371, T-372, T-373, T-374, T-375, T-376, T-377, T-378, T-379, T-380, T-381, T-382, T-383, T-384, T-385, T-386, T-387, T-388, T-389, T-390, T-391, T-392, T-393, T-394, T-395, T-396, T-397, T-398, T-399, T-400, T-401, T-402, T-403, T-404, T-405, T-406, T-407, T-408, T-409, T-410, T-411, T-412, T-413, T-414, T-415, T-416, T-417, T-418, T-419, T-420, T-421, T-422, T-423, T-424, T-425, T-426, T-427, T-428, T-429, T-430, T-431, T-432, T-433, T-434, T-435, T-436, T-437, T-438, T-439, T-440, T-441, T-442, T-443, T-444, T-445, T-446, T-447, T-448, T-449, T-450, T-451, T-452, T-453, T-454, T-455, T-456, T-457, T-458, T-459, T-460, T-461, T-462, T-463, T-464, T-465, T-466, T-467, T-468, T-469, T-470, T-471, T-472, T-473, T-474, T-475, T-476, T-477, T-478, T-479, T-480, T-481, T-482, T-483, T-484, T-485, T-486, T-487, T-488, T-489, T-490, T-491, T-492, T-493, T-494, T-495, T-496, T-497, T-498, T-499, T-500, T-501, T-502, T-503, T-504, T-505, T-506, T-507, T-508, T-509, T-510, T-511, T-512, T-513, T-514, T-515, T-516, T-517, T-518, T-519, T-520, T-521, T-522, T-523, T-524, T-525, T-526, T-527, T-528, T-529, T-530, T-531, T-532, T-533, T-534, T-535, T-536, T-537, T-538, T-539, T-540, T-541, T-542, T-543, T-544, T-545, T-546, T-547, T-548, T-549, T-550, T-551, T-552, T-553, T-554, T-555, T-556, T-557, T-558, T-559, T-560, T-561, T-562, T-563, T-564, T-565, T-566, T-567, T-568, T-569, T-570, T-571, T-572, T-573, T-574, T-575, T-576, T-577, T-578, T-579, T-580, T-581, T-582, T-583, T-584, T-585, T-586, T-587, T-588, T-589, T-590, T-591, T-592, T-593, T-594, T-595, T-596, T-597, T-598, T-599, T-600, T-601, T-602, T-603, T-604, T-605, T-606, T-607, T-608, T-609, T-610, T-611, T-612, T-613, T-614, T-615, T-616, T-617, T-618, T-619, T-620, T-621, T-622, T-623, T-624, T-625, T-626, T-627, T-628, T-629, T-630, T-631, T-632, T-633, T-634, T-635, T-636, T-637, T-638, T-639, T-640, T-641, T-642, T-643, T-644, T-645, T-646, T-647, T-648, T-649, T-650, T-651, T-652, T-653, T-654, T-655, T-65

Figure 8. P&ID No. P-8, high pressure cooling water.

Figure 9. P&ID No. P-9, gas letdown system.

Figure 10. P&ID No. P-10, liquid letdown system.

Figure 11. P&ID No. P-11, evaporation system.

After waste constituents are added to the water in sufficient quantities, a paddle-type mixer capable of creating a homogeneous, or nearly homogeneous, mixture in 15 minutes shall be used to mix the waste constituents and water. It will be necessary to mix the contents of the tank periodically after initial mixing to ensure homogeneity over the duration of the test. Each mixer shall be capable of operating for 15 minutes/hour for a 100-hour test. Operation of the pump and mixers shall be performed manually.

Each tank shall have a level indicator and a high and low-level alarm. Level functions shall be integrated with the control system. The outlet lines on the tanks shall be provided with remote-operated on/off flow control valves. A line and flow control valve shall be routed directly from the deionized water, large storage tank to the low pressure, waste feed line to run clean water through the system for cleaning and startup activities. The low pressure, main feed line shall be provided with a flow measuring and transmitting device that interface with the control and data acquisition system. The flow transmitter shall be interfaced with the high pressure, waste feed pump (see Section 4.3) to adjust flow of liquid (i.e., 0 to 50 gph) in the system. Another control valve shall be located on low pressure main feed line to be used during startup. It will be manually adjusted from the control station and used to transition the feed composition to the reactor from water to waste during initial startup.

Prior to the inlet of the high pressure pump, startup fuel will be added to the main waste feed line. The fuel is required in the wastestream to initiate the oxidation process in the reactor for some low BTU content wastestreams. The fuel will be added from a 55-gal drum, or similar container, using a small metering pump. A flow element and transmitter shall be located downstream of the metering pump and interfaced with the control station. A flow control valve shall be located upstream of where the fuel is injected into the waste line. The flow control valve shall be interfaced with the control room and will receive feedback to automatically adjust the flow of startup fuel based on input from the flow element. A check valve shall be located upstream of the connection of the fuel line to the waste line, preventing back flow of waste into the fuel line. The amount of fuel added to the wastestream will vary depending on the series of waste tested. A pressure relief valve will be located on the low pressure waste feed line. The waste mixing tanks shall be located on the main floor of the high bay area at WRTF Building 646 and allow access during normal operation of the test bed. The waste tanks, supplemental fuel, hazardous materials, and other chemicals used in the waste mixing process shall be contained within a retaining wall.

4.3 High Pressure Waste Transfer

A high pressure (i.e., 0 to 5,000 psig), variable speed pump shall be used to elevate the pressure of the waste feed line to the desired pressure before injection into the reactor. Normal operating pressure is 3,500 to 4,500 psig. The pump will be remotely operated from the control room. The flow rate will be set at the control room, and feedback from the flow element on the low pressure upstream side of the pump shall be used to adjust the flow of liquid. The pump shall be located in the pit.

A pressure relief valve will be located on the high pressure, waste feed line and set for 5,000 psig. The relief valve will either discharge in the pit or to a collection manifold and be routed to the atmosphere. Once pressurized, waste will either be routed through a heater, or directly fed to the reactor.

To quickly moderate the temperature of the waste feed to the reactor, a control valve will be located on the heater bypass line directly to the reactor. The waste will bypass the heater and feed directly into the reactor, or will be mixed with heated waste to quickly reduce the temperature. An electric heater shall be provided to heat the wastestream from between ambient to 572°F. The heater shall be located as close to the inlet of the reactor as

practicable to minimize heat loss of the fluid from the time it leaves the heater until it enters the reactor. As fluid exits the heater, a temperature indicator shall relay information back to the control room, where the temperature is automatically adjusted by a temperature controller. The heater temperature indicator also interfaces with the waste feed bypass control valve to adjust the flow (and, therefore, temperature) of the waste feed. Before entering the reactor, a pressure and temperature indicator shall be located and interfaced with the control room.

4.4 Reactor Mixing Water

Deionized water shall be pressurized, heated, and supplied to the reactor. A line from the 3,000-gal, deionized, water storage tank shall feed a 0 to 5,000 psig (normal operating 3,500 to 4,500 psig) and 0 to 50 gph pump (located in the pit).

A flow element and transmitter shall be located upstream of the pump on the low pressure side and control the flow of liquid to the pump. The flow element shall be interfaced with the control room and provide feedback, so the pump automatically adjusts the flow of liquid. A safety relief valve shall be located on the downstream side of the pump but before the water enters the heater and set for 5,000 psig. The relief valve shall discharge to atmosphere.

After the water is pressurized, it shall be heated from ambient to 1,250°F. An electric heater shall be used to elevate the temperature of the water before it is injected into the reactor. The heater shall be located as close to the inlet of the reactor as practicable to minimize heat loss.

A temperature indicator shall be located on the downstream side of the heater and shall be interfaced with a temperature controller at the control station, which automatically adjusts the temperature to a specified, preset level. A check valve shall be located near the inlet of the water supply line to the reactor to prevent back flow into the line. A temperature and pressure indicator shall be located near the water inlet to the reactor and interfaced with the control room.

4.5 High Pressure Reactor Cooling Water

High pressure cooling water shall be supplied to the reactor and separator at 0 to 5,000 psig (normal operating 3,500 to 4,500 psig) and 0 to 350 gph. A high pressure pump shall be used to supply and pressurize the water. A feed line from the 3,000-gal, deionized, water storage tank will supply water to the pump.

A flow element and flow transmitter shall be located upstream of the pump and interfaced with the control system. A flow controller will automatically adjust the pump to provide the desired flow rate. An acid neutralizer shall be added upstream of the flow element on the low pressure side. Certain waste series containing chlorides, sulfur, and phosphorous shall be neutralized by various chemical agents (specific neutralizing agents have not yet been identified). The neutralizing agents shall be injected into the reactor (and/or separator) by the cooling water line. A 55-gal drum, or similar container, shall be used to dispense the neutralizing agent. A small metering pump shall transfer liquid from the drum to the cooling water line. After the metering pump, a flow element and transmitter shall be located and interfaced with the control station. The flow element shall be interfaced with a flow control valve that automatically adjusts the flow of neutralizer from the tank. A check valve shall be located on the neutralizer line near the connection with the cooling water to prevent water from back flowing into the line.

A pressure safety relief valve shall be located after the high pressure, cooling water pump and set at 5,500 psig. The relief valve shall discharge in the pit. A pressure and temperature transmitter shall be located downstream of the pump and interfaced with the control system.

Before the cooling water enters the reactor, a flow control valve, flow element, and flow transmitter shall be located and interfaced with the control system. The flow control valve will receive feedback through a flow controller and adjust the flow of cooling water into the reactor. A branch from the main cooling water line shall be routed directly to the first stage separator so cooling water (and neutralizing agent) may be injected directly into the first stage separator. An orifice plate shall be provided on this branch line to restrict the flow of cooling water to the separator.

4.6 Oxygen System

A LOX storage vessel sized to hold enough oxygen to support 150 hours of testing shall be provided. The vessel shall be rated for 275 psig. Sufficient pressure shall be maintained inside the vessel so LOX may be transferred to the vaporizer.

The vessel shall be vacuum jacketed to help inhibit heat loss and limit boil off of the LOX. A pressure safety valve shall be provided and set at 290 psig for the inner vessel. A rupture disk, set at 300 psig, shall also be provided for the inner vessel. A rupture disk, set at 30 psig, shall be provided for the outer vessel. A level indicator that can be read manually and interfaced with the computer control system shall be provided with the vessel. High and low alarms shall be included with the level indicator and shall alarm at the control station. The vessel shall be designed so it can be filled from a LOX transport truck. The vessel shall be outside of WRRTF Building 646 and located in accordance with safety standards for oxygen systems. A vacuum-jacketed transfer line shall be routed from the storage vessel to a LOX vaporizer. The internal transfer line shall be protected with a pressure safety valve. The vacuum jacketing shall be protected with a pressure safety valve also. The LOX transfer line feeds LOX to a high pressure pump and vaporizer, which pressurizes the LOX to a maximum of 6,000 psig and then heats the LOX to form GOX.

The vaporizer shall be sized to handle 40 gph of LOX and provide a maximum of 70 SCFM of GOX to the reactor. The vaporizer shall be located in the pit with all other high pressure GOX components. The vaporizer shall be remotely controlled from the control room. A pressure indicator shall be located on the LOX feed line upstream of the high pressure pump. A temperature indicator shall be located on the downstream side of the high pressure pump. Temperature and pressure indicators shall be located on the downstream side of the vaporizer. The temperature and pressure indicators shall be interfaced with the control room to control the rate at which LOX flows through the high pressure pump. After vaporization, the GOX shall be stored in accumulators.

Accumulators are sized to provide 1 hour of GOX (at 70 SCFM) to the reactor at a maximum pressure of 5,000 psig, assuming the vaporizer fails. An on/off control valve regulates the flow of gas into and out of the accumulators and also functions as an isolation valve. The vaporizer and storage system shall be designed for 6,000 psig so the excess pressure will supply oxygen to the reactor at the proper pressure and flow rate. The 6,000 psig pressure in the GOX feed line will also prevent waste from the reactor from back flowing into the GOX line. A flow element, transmitter, and flow control valve are located on the GOX feed line to the reactor to control the flow of GOX to the reactor. The flow elements and control valve shall be interfaced with the control

system to provide for automatic adjustment of the flow rate of GOX to the reactor. At the reactor inlet for the GOX feed line, a lift check valve shall be located to prevent back flow of waste into the GOX feed line.

4.7 First Stage High Pressure Separator

The first stage separator, level indicator, and pressure indicator shall be designed and supplied by the reactor designer. The first stage separator shall be located in the pit. Requirements for the system are identified for interface purposes.

As effluent leaves the reactor, it shall be at a maximum pressure of 5,000 psig and discharged into the first stage separator at a temperature selected by the reactor designer. The effluent shall enter the first stage separator, which is designed to separate gas from the liquid. The separator will be sized to handle twice the volume of maximum effluent flow from the reactor for a period of 6 minutes. Approximately one half of the volume of the separator shall contain gas and the other half liquid. A level indicator shall be located on the separator with high and low alarms and interfaced with the control system. The level indicator shall be interfaced with a control valve located on the liquid effluent discharge line from the separator. The valve will control the rate of flow of fluid through the discharge line, and therefore, the level of liquid effluent in the separator.

As effluent enters the separator, gas and liquid are separated. Gas is routed through a line to a pressure let down and filtering system (see Section 4.8). The liquid exits the separator at a maximum pressure of 5,000 psig and maximum temperatures of 482°F for acidic effluent and 572° F for nonacidic effluent. A means for obtaining a fluid temperature measurement shall be located near the liquid outlet of the separator and interfaced with the control system to provide the temperature of the exiting effluent. The temperature indicator shall be interfaced with an alarm at the control room to warn of high liquid temperature. A pressure indicator is located near the top of the vessel and is interfaced with the gas flow control valve and control system to adjust pressure inside the vessel. At maximum operating conditions, approximately 400 gph of effluent shall pass through the first stage separation vessel.

A series of orifice plates shall be located on the liquid discharge line. The orifice plates shall reduce the pressure from 5,000 to a minimum of 2,000 psig. The orifice plates shall be designed for easy removal from the line for cleaning, inspection, and replacement. After the orifice plates, the flow control valve, which is interfaced with the level controller for the first stage separator, is located. It shall drop the pressure from 3,000 to 1,500 psig. The line is then routed to the second stage separator.

4.8 Gas Emission

As gas is separated in the first stage separator, it exits the vessel and is routed through a series of orifice plates that reduce the pressure from 5,000 to a minimum of 2,000 psig. The maximum temperatures are 482°F for acidic gas and 572°F for nonacidic gas. The flow rate of gas from the first stage separator will vary from 1 to 30 ACFH. Downstream of the orifice plates, a flow control valve shall be located. This control valve is interfaced with the pressure indicator on the first stage separator and control system. The valve controls the flow of gas to maintain a constant pressure (and quantity) of gas in the separator. The control valve further reduces the pressure from 3,000 to 25 psig.

After the gas flows through the control valve, it enters a cyclone separator that separates the gas and any remaining liquids and solids. A sample port shall be located at the base of the cyclone separator that allows solid and liquid samples to be manually collected (when the system is not operational).

A gas line from the second stage separator tees into the main gas feed line from the first stage separator. The gas then enters a series of filters designed to absorb volatile organic compounds and mercury from the gas. The gas is then released to atmosphere. The filters shall be designed to ensure all gas emissions are within regulatory limits.

4.9 Second Stage High Pressure Separator

Liquid from the first stage separator is transferred through a series of pressure let down elements and enters the second stage separator at a maximum pressure of 3,000 psig, (normal operating is 600 psig) maximum flow rate of 400 gph, and maximum temperature of 482°F for acidic effluent and 572°F for nonacidic effluent. A series of nozzles shall be located inside of the vessel that are designed to reduce the pressure to 50 psig and spray the liquid on the side of the vessel, liberating gas from the effluent.

The second stage separator is sized to accommodate twice the maximum flow from the first stage separator based for a period of 1 1/2 minutes. The normal operating pressure inside the second stage separator shall be 50 psig.

The design pressure is 500 psig. A pressure safety valve shall be located on the vessel. A liquid level indicator (with high and low level alarms) shall be located on the separator and interfaced with the control system and a flow control valve on the liquid discharge line from the second stage separator. The level indicator shall provide feedback to the control system, which automatically adjusts the flow of liquid through the control valve, maintaining a constant level of fluid in the separator. The liquid flow control valve also serves to reduce the pressure of the effluent from the separator from 50 psig to just over atmospheric. A pressure indicator shall be located on the separator, which shall be interfaced with the control system (a high pressure alarm shall also be provided). The pressure indicator shall also be interfaced with a gas flow control valve located on the gas discharge line from the second stage separator. The gas control valve shall receive feedback from the pressure indicator and automatically adjust the flow of gas through the line to keep the gas pressure constant in the separator.

As liquid leaves the separator, it is passed through a small shell and tube heat exchanger. It is required to lower the temperature of the effluent to precipitate out as many solids as possible before the effluent passes through the effluent filter. The effluent shall be on the tube side of the heat exchanger, and cooling water (from a raw water supply) shall be on the shell side. The effluent shall be cooled to 80°F after passing through the heat exchanger. The raw water from the heat exchanger is routed to an existing floor drain in WRRTF Building 646 and to an existing evaporation pond. After the heat exchanger, the liquid level flow control valve is located on the effluent discharge line. A filter designed to capture 98%+ of all suspended solids (maximum particle size 100 microns, minimum particle size 1 micron) in the effluent is then located on the discharge line. The filter shall be designed so it can be removed during testing and the collected solids analyzed. Multiple filters will be required, so if one filter fails, the other may be used without shutting down the test, and so new filter elements may be added during testing.

After filtering, the liquid is routed to the effluent storage tanks. Gas from the second stage separator is routed to the gas filters.

4.10 Effluent Storage and Discharge

The effluent from the second stage separator is let down to nearly atmospheric pressure, filtered, and routed to two storage tanks. The combined volume of both tanks shall be sized to hold all liquid generated during a 10-hour test. For longer duration tests, one tank will be filled while the other is drained. Each tank shall be provided with level controls and high level alarms. The effluent in the tanks shall be mixed to a homogenous state. A sample will be acquired after the tank is full (or a test is complete), analyzed, and the effluent determined to be hazardous or nonhazardous. If nonhazardous, the effluent shall be routed to the WRRTF evaporation pond for final disposal. If the effluent is hazardous, it will be routed to an evaporator. The evaporator shall be electric and capable of boiling off a maximum of 400 gph of effluent. The maximum solids in the effluent will be 100 ppm. The maximum salt content of the effluent is 7.6 lb/hour of flow. The maximum, nonsalt, dissolved solids content of the effluent is 0.64 lb/hour. Most of the effluent shall be water with oxygen and some wastes in solution. The evaporator shall be provided with removable trays and a system for draining slurry like effluent. After testing, the trays shall be removed and any sludge or solid matter collected, analyzed, and disposed. Likewise the slurry shall be drained, analyzed, and disposed. The evaporator shall be located outside and control of the evaporator shall be interfaced with the control system so operation may be performed remotely and upset conditions are alarmed.

4.11 Utilities

The following utilities shall be provided for in the test bed design:

- **Nitrogen Purge**—A nitrogen purge shall be supplied to the high pressure waste feed, high pressure cooling water, high pressure mixing water, high pressure gas let down, high pressure liquid let down, and oxygen systems. A nitrogen purge shall be provided to each gas sampling line. Nitrogen purges to other systems may be required as well and shall be identified on the P&IDs. K bottles shall be used to supply nitrogen. Two K bottles shall be located indoors on the main floor of WRRTF Building 646, and a manifold shall be used to deliver nitrogen to the required lines. Nitrogen tubing will be routed to the general location of the purge connection point, and a quick disconnect and flex hose will be used to supply the nitrogen to the line. A flow control valve shall be used to moderate the pressure in the nitrogen purge line. Local pressure indicators shall be located upstream and downstream of the control valve and on each purge line. A pressure safety relief valve shall be located on the nitrogen purge line and set for 50 psig. Operation of the purge system shall be performed manually (i.e., opening and closing of valves to route the nitrogen shall be performed by personnel). No portion of the purge system is interfaced with the control system.
- **Raw Water**—Raw water shall be supplied to the effluent discharge line heat exchanger from the second stage separator. The water shall be supplied from the existing plant water system at WRRTF. A flow of 60 gpm shall be the maximum quantity of water used for cooling. Flow elements shall be located on the raw water feed line and interfaced with the control system to indicate that liquid is flowing through the line and at what rate. After use, the raw water is released through an existing drain system. The water exits through a floor drain and is routed to the existing WRRTF evaporation pond.

- **Instrument Air—**WRRTF Building 646 has an existing instrument air compressor (approximately 150 psig) that shall be used for supply of compressed air to instruments (assuming no drying, filtering, or other treatment of the air is required). Currently, it is anticipated that only a few instruments shall use instrument air, and the capacity of the existing system will be able to meet the required demand.
- **Safety Relief Device Collection System—**For systems with hazardous liquids or gases, fluid at high temperatures, or LOX or GOX, a collection system shall be provided in the event of a rupture of a safety relief device. A piping header will route the gas or liquid from the point of rupture to the atmosphere. An analysis shall be performed during the detailed design to determine how many lines are required.
- **Gas Vent Lines—**Vent lines for the supplemental fuel drum, neutralizing agent drum, waste mixing tanks, and waste storage tanks shall be provided to route gas from the point of discharge outside of Building 646 to the atmosphere. An analysis shall be performed during the detailed design to determine how many vent lines will be required.

5. SAFETY AND ENVIRONMENTAL REQUIREMENTS

Design requirements for safety (i.e., personnel and environment) of engineered systems are contained in various codes and standards that are used for design of pressure and energy systems (see Section 3.2). Additional safety standards for the design of the SCWO test bed are contained in the EG&G Idaho *Safety Manual*. The design shall comply with all applicable Federal, state, and local health, safety, and environmental codes. The following are key safety and environmental issues associated with the design of the SCWO test bed:

- High pressure and high temperature systems shall be remotely operated because the SCWO test bed is comprised of several high pressure and high temperature systems carrying hazardous materials.
- All pressurized systems shall be provided with at least one device specifically designed for overpressure relief. All ASME code vessels shall be provided with individual safety relief devices. All piping systems shall be evaluated for where pressure relief shall be provided based on accidental valve, component, or equipment failures that would cause build up of excess pressure. Burst pressures shall be no higher than allowed by the governing design code. Burst pressures may be lower than code requirements depending on process and safety requirements for a specific system.
- An evaluation shall be performed by the project to determine an environmentally acceptable method for handling discharge from ruptured safety devices. The safety devices will be located on liquid and gas systems containing hazardous materials or wastes.
- In addition to remote operation, the high pressure and high temperature systems shall be shielded from personnel. It is planned to locate the test bed in the north pit at WRRTF. This configuration shall allow the high pressure portions of the plant to be located in a concrete lined pit, approximately 30 ft deep. It will be determined during the safety analysis (performed by the program) if a cover is required over the pit. If required, a structural steel cover shall be placed over the top of the pit for further protection. As a minimum, a cover is required over the oxygen accumulators to protect them from objects that could be dropped by the overhead crane.
- The north pit shall also serve as a means for containment of fluids in case of a spill or emergency condition. This containment may require the application of a mastic or suitable material to the surface of the concrete to ensure there is no leakage. Any penetrations, drains, or other openings in the pit walls or floor shall need to be sealed. It may be required to install a low point sump in the pit and slope the floor so fluid will collect in the sump. An assessment and required follow on work shall be performed by the SCWO program to determine if the pit will need to be sealed.
- Location of the LOX storage tank will be in accordance with design guidance contained in 29 CFR 1910, Section 104 "Installation of Bulk Oxygen Systems." Factors such as proximity of the tank to buildings, structures, and flammable materials, cleanliness, protective berms, and delivery and transfer of LOX are identified in this specification.

- Protective berms or containment walls with appropriate liners (for spill containment and collision prevention) will be required around the waste mixing tanks, neutralization barrel, supplemental fuel barrel, and effluent storage tank, or any other tank, vessel, or container not located in the north pit and containing hazardous materials or wastes. The waste mixing tanks shall be designed so that adequate space is provided to locate containers of hazardous materials within the bermed area. In this manner, the hazardous materials are contained as they are added to mixing tanks. Design (with emphasis on containment and spill prevention and detection) of all tanks, vessels, piping, equipment, or other test bed components containing hazardous materials or wastes shall be performed in accordance with 40 CFR 265 "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment Storage, and Disposal Facilities."
- An oxygen monitoring system shall be installed in the north pit. A series of oxygen monitors shall be located in the pit and capable of detecting either an abnormally high or low concentration of oxygen in the air. A high concentration indicates a leak in the oxygen supply system, while a low concentration indicates a potential leak in the process equipment or piping. The monitors shall be designed to alarm both locally and at the control console when an abnormal condition is detected.
- The program shall perform an evaluation to determine if an HVAC system is required in the north pit. During operation of the test bed, considerable heat will be generated by the equipment and piping in the north pit. For personnel safety and comfort, an HVAC system may be required to maintain a reasonable temperature in the pit.
- The program shall perform an evaluation to determine the suitability of the SAW control room for locating the test bed control console. A question has been raised concerning two points of egress from the room in the event of an emergency (currently only one exists from the main floor area of Building 646).
- Based on a cursory review of information contained in the State of Idaho's *Notice of Proposed Rules—Department of Health and Welfare, Rules Governing Air Pollution Control*,⁷ three constituents are identified that could exceed regulatory air emission limits. Benzene, hydrochloric acid, and mercury, in a worst case upset condition scenario, could exceed the proposed air emission limits. It is planned to filter all gas (most of which is composed of oxygen, carbon dioxide, and carbon monoxide) through a series of carbon filters and then vent it to the atmosphere. The filters shall be designed to strip hazardous constituents from the gas. The gas composition will meet regulatory requirements when vented to the atmosphere. This approach may or may not be acceptable to the regulators and could require significant modification. Any modifications shall not be known until an air permit is formally submitted to the state, and comments are received. The air permitting process with DOE and the State of Idaho could be a lengthy undertaking and require design changes at a later date. It is suggested that the permitting process be started as soon as possible to ensure as changes are identified and incorporated into the design
- As described for air permitting, the same permitting and review process and potential for design changes exist for disposal of RCRA wastes and effluent treatment.

The process and control systems shall incorporate human factors design into the logic and operation of the test bed. Consideration shall be given to control of the system during normal operation with emphasis on emergency response and safe shutdown during upset and alarm conditions. Each process shall be evaluated for (a) the need for level, pressure, temperature, or other types of alarms to alert an operator of an upset condition, (b) pressure relief in the event of operator error and equipment failure, and in the event of an emergency condition, all systems shall incorporate a means for pressure relief to prevent explosions or rupturing of system components, (c) automatic control of process elements such as temperature, flow, and pressure shall be evaluated to ensure that modulation of these elements are performed by the control system with minimum operator intervention, and (d) interlocks; an evaluation shall be performed to determine what emergency and alarm conditions require automatic shutdown of other portions of the process system.

6. QUALITY ASSURANCE

The SCWO test bed shall be designed in accordance with the requirements of Quality Program Plan, QPP-044, Engineering Research and Applications Quality Program Plan and the Office of Waste Technology Development supplement. The *Supercritical Water Oxidation Hazardous Waste Test Bed Data Quality Plan* shall be used as a reference for data quality objectives. Applicable portions of the EG&G Idaho *Quality Manual* shall also be used for the design.

A Configuration Management Plan shall be prepared by the project and used to manage and control the overall configuration of the design including generation, approval, and change control of drawings, specifications, electronic files, and related project documentation produced during the preliminary and final design phases.

7. REFERENCES

1. C. Shapiro, *Supercritical Water Oxidation Test Bed Functional & Operational Requirements*, EG&G Idaho, Inc., F&OR-232, EG&G Idaho, Inc., EGG-WTD-11200, 1994.
2. C. M. Barnes, *Mixed Waste Survey for Supercritical Water Oxidation Program*, EG&G Idaho, Inc., EGG-WTD-10984 November 1993.
3. EG&G Idaho, Inc., "Procurement," *Company Procedures Manual*, Volume I, Section 3.
4. R. M. Latanision and R. W. Shaw, *Corrosion in Supercritical Water Oxidation Systems: Workshop Summary*, Massachusetts Institute of Technology, MIT-EL 93-006, September 1993.
5. Idaho National Engineering Laboratory, *Site Development Plan, Site Characteristics*, Volumes I and II.
6. J. M. Svoboda, *Supercritical Water Oxidation Hazardous Waste Pilot Plant Data Quality Plan (DQP-11980)*, EGG-WTD-11023, February 1994
7. State of Idaho, *Notice of Proposed Rules-Department of Health and Welfare, Rules Governing Air Pollution Control*, February 1994

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