HYDROTHERMAL OXIDATION HAZARDOUS WASTE PILOT PLANT TEST BED

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ABSTRACT

The Idaho National Engineering Laboratory (INEL) is fabricating a Hydrothermal Oxidation (HTO) Hazardous Waste Pilot Plant Test Bed to evaluate and test various HTO reactor concepts for initial processing of the U.S. Department of Energy (DOE) mixed wastes. If the HTO process is successful it will significantly reduce the volume of DOE mixed wastes by destroying the organic constituents.

INTRODUCTION

The technology has been successfully demonstrated at bench and pilot plant scales for a limited number of wastes, but there are some questions that must be resolved and some risks evaluated before HTO can be used to process DOE mixed wastes. The HTO Hazardous Waste Pilot Plant Test Bed being fabricated by the INEL will evaluate several commercially available HTO reactor designs, such as transpiring wall, vessel, and tubular reactors to investigate those questions and risks. Following HTO reactor testing and evaluation the Test Bed will be used for support system evaluation and development.

Simulated waste and water mixtures with flows up to 50 gallons per hour, temperatures up to 300 °C, and pressures up to 5000 psia will be supplied to the reactor. De-ionized water will also be supplied at up to 50 gallons per hour, 620 °C, and 5000 psia. Gaseous oxygen will be supplied at 5 to 70 SCFM at ambient temperature and up to 5000 psia. Up to 350 gallons per hour of cooling water flow at 5000 psia can also be supplied to the reactor or downstream high pressure components. Tests are expected to last from 10 to 100 hours.

Gaseous and liquid effluent samples can be taken while the test is underway. Gas samples will be taken from several locations in the gas discharge line and analyzed by a residual gas analyzer. Analysis results will be stored in the data collection system and can be monitored during the test. Liquid samples will be collected in evacuated sample bombs at selected times during the tests. At test completion the sample bombs
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will be retrieved and sent to the laboratory for analysis.

**FACILITY**

The test bed will be located in the Water Reactor Research Test Facility (WRRTF) an existing facility on the northern part of the INEL. Figure 1 is an aerial view of the complex. The test bed will be located in the high bay building on the right side of the figure. There are cafeteria services, fire protection, security, and crafts personnel and shops within a few miles of the site.

The high bay is 142 foot long by 46 foot wide by 46 foot high. Two concrete lined pits 26 foot wide by 40 foot long by 28 foot deep with a 3 foot high parapet wall all around are located in the center of the high bay area. A large laydown area is located to the north of the north pit. A bridge crane with 50 ton and 5 ton hoists is available for handling heavy equipment in the pits and laydown area. The maximum hook height is 31 foot above the main floor (59 feet above the floor of the pit).

Three phase electrical power at 480 volts and single phase power at 120 volts is available at convenient locations throughout the building.

Three and a half megawatts of DC power is also available. The test bed will be using 1.5 megawatts of the DC power for the clean water, simulated waste heaters, and an evaporator.

Raw water, de-ionized water, and softened water, plant and instrument air are also available. There is adequate space for offices and craft shops.

Figure 2 shows the location of the test bed equipment. The simulated waste mixing and preparation area is located just to the north of the northern pit. This area is accessible to test personnel at all times during a test. The control room is located to the north-east of the simulated waste mixing area. A window in the control room wall allows the operators to monitor the test area.

High pressure and high temperature equipment that could pose a hazard to personnel or equipment has been located in the north pit. The reactor vessel, first and second stage letdown/separator vessels, clean water and simulated waste heaters, and the oxygen vaporizer are located in the pit.

The gaseous effluent is vented from the building through charcoal filters which are located on the northwest side of the pit. The liquid effluent is temporarily collected in two 3000 gallon holding tanks located on a platform above the south pit. An evaporator is also located on this platform. The evaporator simulates the operations required to reduce the volume of the actual radioactive waste materials by driving off as much liquid as possible.

The de-ionized water supply tank is an existing 3000 gallon aluminum vessel located one floor below the main floor.

**EQUIPMENT LOCATED IN PIT**

Figure 3 shows the equipment that has been located in the pit. Two electric heater assemblies used to heat the simulated waste and clean water are located north of the reactor support structure as close to the reactor as practical. The simulated waste can be heated up to 300 °C (572 °F) and the clean water up to 620 °C (1148 °F). The heating elements are clamped to the outside of the simulated waste and clean water supply piping. No penetrations are made through the high pressure piping.

The simulated waste system piping is made from 3/4 XXS Hastelloy and the clean water system piping is 1/2 XXS 316L stainless steel. The piping is welded with full penetration butt weld connections wherever possible. When mechanical connections are required Reflange hubs and clamps are used.

The reactor vessel is located in the center of the pit inside an existing steel support structure. The supply and effluent piping supplied by the test bed is anchored to the support structure and is provided with a Reflange type hub. Piping from these end points to the various reactor nozzles will be custom built for each reactor type. Generally, this piping will be supplied by the reactor supplier. Reactor support brackets and fixtures will be attached to the support structure as required.

A control valve and orifice assembly will be installed between the reactor assembly and the first stage separator vessel to reduce the pressure to about 1000 psig. The control valve will be used to control the pressure in the reactor by a signal from a pressure...
transducer in the reactor or piping immediately downstream of the reactor.

The orifice assembly is a set of orifice plates positioned in series in a 1-1/2 inch diameter XXS pipe spool that will be used to help reduce the pressure of the fluid leaving the reactor. The individual orifice plates can be easily changed which will allow us to use the same control valve over a wider flow range by adjusting the orifice sizes to remove more or less energy through the orifice plate assembly. The orifice plate assembly also helps reduce cavitation and erosion on the control valve by reducing the fluid energy that must be removed by the valve.

The first stage separator vessel separates about 90% of the oxygen and 50% of the carbon dioxide from the liquid stream. The vessel pressure will be held at 1000 psig by a control valve in the gaseous outlet line. The gasses leaving the vessel are reduced in pressure from 1000 psig to just above atmospheric pressure by the pressure control valve and orifice assembly. The gas is then vented from the building.

Liquid and the remaining entrained gas will flow from the first stage separator to the second stage separator vessel through a control valve and orifice assembly. The second stage separator vessel pressure is held at 60 psig by a control valve in the gaseous outlet piping. The remaining oxygen and carbon dioxide will be separated from the liquid in this vessel. The gas exiting the second stage separator is combined with the gas from the first stage separator vessel downstream of the pressure control valve and is vented from the building.

All high pressure piping downstream of the reactor vessel is made from 3/4 XXS Hastelloy. Moderate pressure liquid piping between the first and second stage separator vessels is also made from 3/4 XXS Hastelloy. The low pressure gaseous and liquid piping is made from 316L stainless steel of various sizes. Where possible, all joints are butt welded to minimize crevices which could trap corrosives.

The liquid in the second stage separator vessel is pushed up out of the pit to the 3000 gallon holding tanks by the pressure in the second stage separator. Vessel level is controlled by a control valve in the liquid outlet piping.

A small heat exchanger is installed in the liquid line downstream of the second stage separator. The heat exchanger cools the water leaving the second stage separator low enough to allow the operators to quickly change filter elements in a filter assembly located on the main floor. This allows samples of entrained solids to be collected at various times during a test.

Personnel are not allowed in the pit area when system is at pressure or temperature. All valves that require operation during a test are remotely operated and all pressures and temperatures are displayed in the control room. Additionally, 3 video cameras and 2 microphones are located in the pit so the operators can observe and listen to conditions in the pit at any time.

The oxygen system vaporizer and accumulators are located in the pit along the east wall. The vaporizer converts the high pressure liquid oxygen to a gas at near ambient temperature. The accumulators provide a small volume of high pressure oxygen to maintain the oxygen system at a pressure higher than the reactor systems to allow an orderly shutdown of the test bed should the oxygen supply be lost. Maintaining the oxygen at a pressure above the reactor systems prevents organic materials from back flowing into the oxygen system.

SIMULATED WASTE PREPARATION

Figure 4 shows the simulated waste preparation area. Two six-hundred gallon tanks with electric motor driven paddle mixers are provided for mixing simulated wastes that are water soluble or will remain evenly dispersed in water. Each tank will provide 10 hours of operation. The tanks will be used in batch mode for tests longer than 20 hours by mixing the chemicals in one of the tanks while the other tank is supplying the test bed. The tanks are fabricated from fiberglass reinforced plastic and are covered to prevent undesirable materials from falling into the tanks and to prevent uncontrolled release of vapors from the tanks. Tank vapors are ducted out of the building through a 4 inch diameter PVC pipe connected to a small fan.

The mixers are driven by 1/2 horse power 115 volt single phase motors.

The agitators are fabricated from 316 stainless steel and rotate at 350 RPM.

For those simulated waste solutions that cannot be
mixed with water, the concentrated solution can be placed directly into one of the tanks. One tank should hold enough for a 100 hour test.

Liquid from the tanks is directed to the high pressure waste pump located near the north wall of the pit. Piping from the tank to the pump suction is fabricated from 3/8 inch Schedule 40 316L stainless steel. Remote actuated isolation valves are provided at each tank outlet to allow operators in the control room to select either tank.

The mixing tanks are manually filled with water through a 1-1/2 schedule 40 316L stainless steel line from the de-ionized water supply tank. A manually operated valve is located at the inlet to each tank. Simulated waste chemicals can be poured in through a port in the tank cover or pumped in using a 55 gallon drum and portable barrel pump. Each tank is provided with a liquid level detector that can be monitored at the tank and in the control room.

The simulated waste can also be pumped directly into the line through one of sample ports located in the piping from the tank to the simulated waste high pressure pump.

De-ionized water can be supplied to the suction of the high pressure simulated waste pump to mix with the concentrated waste from the mixing tank.

Sample lines with manual isolation valves are provided so liquid samples can be collected to verify the mixture or provide a record of the fluid processed in a particular test.

HIGH PRESSURE PUMPS

The simulated waste and mixing flow high pressure pumps are electric motor driven triplex plunger pumps with fixed stroke. Flow rate is adjusted from 5 to 50 gallons per hour using a variable frequency drive. The pumps can supply this flow rate up to 5000 psig. The pumps are located in the simulated waste mixing area near north wall of the pit, see Figure 4.

Piping from the outlet of the simulated waste pump is 3/4 XXS Hastelloy and from the outlet of the mixing flow pump is 1/2 XXS 316L stainless steel. The piping is routed to the electric heaters located in the pit.

Flow from the simulated waste pump and the mixing flow pump will be combined at the inlet to the reactor. The flow from each pump will be adjusted to provide the proper mixture temperature and waste composition. The total flow from both pumps will normally not exceed 50 gallons per hour.

COOLING WATER SUPPLY SYSTEM

A 350 gallon per hour positive displacement cooling water pump is located on the main floor north of the pit. The coolant supply can be directed to the reactor and to any high pressure vessels or systems downstream of reactor vessel. Cooling water flow rate is controlled by a variable frequency controller on the pump motor. The flow is directed to the various devices by remotely operated valves in the piping to the component. A relief valve is installed in the pump discharge line to protect the system in the event the operator inadvertently closes all system valves. Figure 4 shows the location of the cooling water pump.

EFFLUENT SAMPLE SYSTEM

Gas samples will be collected from several points in the gas effluent line at selected times during a test and evaluated with an on line residual gas analyzer. Analysis results will be stored in the test bed data collection system.

Liquid samples will be remotely collected in evacuated sample bombs at selected times during a test. After the test is completed and the system depressurized the samples will be retrieved and sent to the analysis laboratory.

LIQUID COLLECTION AND DISPOSAL

Liquid effluent will be collected in one of two 3000 gallon collection vessels. Figure 5 shows the location of the liquid collection vessels and the evaporator. The vessels will hold all of the liquid expected from a 10 to 20 hour test. For tests longer than 20 hours the liquid in the holding tanks will be processed. The liquid will be sampled and analyzed and disposed of by draining to an evaporation pond or to an electrically heated evaporator depending on the sample results. The residuals left in the evaporator will be placed in drums and disposed of at an approved hazardous waste site.
OXYGEN SUPPLY SYSTEM

Figure 6 shows the liquid oxygen storage vessel and high pressure pump. A liquid oxygen and pump vaporizer system was selected for bulk storage of the oxidizer because of the large volume of oxygen required for the longer tests. The liquid oxygen is pressurized to 5000 psig with a high pressure pump then vaporized to supply gaseous oxygen at about ambient temperature to the reactor.

The high pressure pump is located near the liquid oxygen storage vessel to minimize heat leakage into the liquid oxygen between the vessel and the pump to reduce the potential for pump cavitation. The vaporizer is located in the pit to place the vaporizer in a less harsh environment (outside temperatures can reach 40 °F below zero with a foot or so of snow in the winter) and to minimize personnel exposure to the high pressure gaseous oxygen system.

The liquid oxygen storage vessel is vacuum and perlite insulated with a capacity of 6000 gallons. The vessel operating pressure is 75 psig.

High pressure oxygen system piping and components are made from monel to minimize the potential for ignition.

CONTROL AND DATA ACQUISITION SYSTEM

The control and data acquisition system consists of a SUN SPARC station processor running National Instruments LabView. An operators console will be located in the control room and two process interface cabinets will be located on the main floor near the test bed. The cabinets contains low and high analog inputs, voltage and current outputs, digital I/O and serial communication interfaces. The system uses a graphically oriented user interface that performs data acquisition, data display, control, and archival functions.

DE-IONIZED WATER SUPPLY SYSTEM

The existing demineralizer system is capable of processing raw water at 30 gallons per minute. Approximately 7400 gallons of water can be processed before the resin column has to be regenerated. Water resistivity at the outlet of the demineralizer is less than 0.5 megohm and solids content is less than 0.5 ppm. It will take two to three hours to regenerate the column when the water quality leaving the system begins to degrade. Water quality is measured by a conductivity element at the outlet of the resin column.

Demineralized water is stored in a 3000 gallon aluminum tank. For tests less than eight hours long the tank will hold enough water for the entire test. For longer tests the tank will have to be refilled and the resin column will have to be recharged during the test.

The demineralized water is only used for the HTO reactor supply.

DC POWER SUPPLY SYSTEM

The "transrex" direct current power supplies are left over from an earlier test facility that performed light water reactor blowdown experiments using electric heat to simulate heat from the nuclear core. The test facility was shutdown in 1984.

Seven power supplies provide variable voltage and variable current DC power. Each unit generates 500 kW at up to 400 volts DC using 4 125 kW SCR power supplies connected in parallel, series-parallel, or series for a unit output voltage of 100 VDC, 200 VDC, or 400 VDC, respectively. Power output is controlled by the SCR gate firing angle. As the firing angle decreases the output increases due to a greater percentage of the input AC sine wave being conducted to the output. Each SCR ceases conduction as its current goes to zero each AC half cycle.

NITROGEN PURGE SYSTEM

Two nitrogen purge systems are provided, one for the oxygen system to prevent contaminants from back flowing into the oxygen system piping and one for maintenance activities. The oxygen system nitrogen purge system supplies 200 psig nitrogen to the oxygen line near its inlet to the HTO reactor. The system is turned on prior to pressurizing the reactor which causes a small amount of nitrogen to flow into the reactor. When the HTO and the oxygen system are pressurized to operating pressures, a check valve in the purge line is forced closed. The purge system remains pressurized at 200 psig throughout the test but flow is prevented by the closed check valve. Purge flow automatically starts again at the end of the test when
the HTO system is depressurized. Overpressurizing the nitrogen line is prevented by installing 2 check valves in series with a pressure alarm and relief valve located between the check valves. Thus, if the downstream check valve starts to leak, the operator will receive an alarm at the control console and the relief valve will open and discharge fluid. Two banks of three nitrogen cylinders are located on the main floor to supply nitrogen to the purge system. Dual pressure regulators are installed that automatically switch to the full cylinder bank when one bank is depleted and send an alarm to the operator console warning the operator that the nitrogen supply is getting low.

The other nitrogen purge system is connected to the system only during maintenance activities. Manual isolation valves and quick disconnects are installed at selected locations throughout the HTO system. The system can be used to blow residual water out of a line so maintenance can be performed, or to pressurize a line for leak checking purposes, and so on. Three nitrogen cylinders are located on the main floor with tubing routed to the various purge locations on the HTO systems.
FIGURE 1 - HTTO Test Bed will be located in an existing INEL facility.
FIGURE 2. HYDROTHERMAL OXIDATION HAZARDOUS WASTE PILOT PLANT TEST BED EQUIPMENT LAYOUT
FIGURE 5. LIQUID COLLECTION SYSTEM IS LOCATED ON PLATFORM ABOVE SOUTH PIT.
FIGURE 6. LIQUID OXYGEN STORAGE TANK AND HIGH PRESSURE PUMP ARE LOCATED OUTSIDE OF BUILDING