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PNL-10146
UC-900

Final Project Report

**Dual Shell Pressure
Balanced Reactor Vessel**

R. J. Robertus
A. G. Fassbender

October 1994

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

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Final Project Report

Dual Shell Pressure Balanced Reactor Vessel

R. J. Robertus
A. G. Fassbender

October 1994

Pacific Northwest Laboratory
Richland, Washington 99352

Dual Shell Pressure Balanced Reactor Vessel

Staff exchanges are intended to facilitate communication and collaboration among scientists and engineers at Department of Energy (DOE) laboratories, in U.S. industry, and academia. Funding support for exchanges is provided by the DOE, Office of Energy Research, Laboratory Technology Transfer Program. The exchanges offer the opportunity for the laboratories to transfer technology and expertise to industry, gain a perspective on industry's problems, and develop the basis for further cooperative efforts through Cooperative Research and Development Agreements (**CRADAs**) or other mechanisms.

Introduction

The Department of Energy's Office of Energy Research (OER) has previously provided support for the development of several chemical processes, including supercritical water oxidation, liquefaction, and aqueous hazardous waste destruction, where chemical and phase transformations are conducted at high pressure and temperature. These and many other commercial processes require a pressure vessel capable of operating in a corrosive environment where safety and economy are important requirements. Pacific Northwest Laboratory (PNL) engineers have recently developed and patented (U.S. patent 5,167,930 December 1, 1992) a concept for a novel Dual Shell Pressure Balanced Vessel (DSPBV) which could solve a number of these problems. The technology could be immediately useful in continuing commercialization of an **R&D** 100 award-winning technology, Sludge-to-oil Reactor System (STORS), originally developed through funding by OER.

Innotek Corporation is a small business that would be one logical end-user of the DSPBV reactor technology. Innotek is working with several major U.S. engineering firms to evaluate the potential of this technology in the disposal of wastes from sewage treatment plants. PNL entered into a CRADA with Innotek to build a bench-scale demonstration reactor and test the system to advance the economic feasibility of a variety of high pressure chemical processes.

Hydrothermal processing of corrosive substances on a large scale can now be made significantly safer and more economical through use of the DSPBV. Hydrothermal chemical reactions such as wet-air oxidation and supercritical water oxidation occur in a highly corrosive environment inside a pressure vessel. Average corrosion rates from 23 to 80 mils per year have been reported by Rice (1994) and Latanision (1993). The actual observed corrosion is often uneven, and pitting is sometimes observed. In addition, 316 stainless steel, **Inconel** 625, and Hastelloy C-276 have exhibited stress-corrosion cracking when used as pressure vessels for hydrothermal processes. Differential thermal expansion, uneven corrosion, pitting and stress-corrosion cracking limits the use of lined vessels. Undetected breached linings could lead to prolonged hidden corrosion of the pressure vessel. The DSPBV vessel eliminates costly choices between strength and corrosion resistance; between temperature, pressure, and vessel life; and between safety and effective operation and maintenance. This new technology combines ordinary steel, specialty metal alloys, and ceramics in a unique, patented design to meet the challenges of corrosive chemistry in pressurized processes.

The DSPBV uses a separate inner shell, inside a pressure vessel insert that **fits** close to the wall of the outer shell of the pressure vessel. The insert is constructed of a metal or alloy such as **Inconel**, Hastelloy, **zirconium**, titanium, tantalum, titanium-tantalum, titanium-niobium, or a ceramic such as **as** alumina. A pressure-transfer fluid, such as Syltherm 800® or water, is placed in the annulus between the pressure vessel and the specialty material insert or working reactor. The pressure-transfer fluid is kept physically separate and in hydrostatic equilibrium with the fluid entering the reactor. The pressure balancing is achieved by an external piston or by allowing the insert to change volume to respond to pressure and thermal forces. Because the fluid pressure is balanced on both sides of the insert, the insert is not under significant stress, so stress-corrosion cracking is minimized. The insert's thickness is determined by corrosion potential rather than strength; thus, it must only be thick enough to support its own weight and act **as** an envelope to separate the corrosive reactants from the steel pressure vessel. The DSPBV design provides adequate space between the insert and the pressure vessel to allow for any degree of differential thermal expansion. The strength and corrosion resistance specifications of the pressure vessel are decoupled from the specifications of the insert. Specialty metal pressure vessels are expensive, not only because a large amount of metal must be used for strength, but because they are challenging to weld, fabricate, and certify. The patented DSPBV design combines steel and specialty metals to let designers select the optimum materials for corrosion resistance of the inner shell separate from pressure vessel considerations.

The outer shell, or pressure vessel, is constructed of carbon or chrome-moly steel components such as extra heavy pipe and standard 2500 pound class steam fittings. Carbon steel and chrome-moly steel are much less costly to buy and fabricate into pressure vessels than are exotic alloys and specialty metals.

While the pressure-transfer fluid balances the pressure, its electrical properties are continuously monitored to ensure the integrity of the insert. A significant change in conductivity of the pressure-transfer fluid alerts operators to a breach of the inner reactor so it can be replaced before the steel pressure vessel corrodes. The ability to continuously monitor the integrity of the working reactor is a fundamental safety advance for this industry.

The DSPBV working reactor unit is designed to monitor, protect, and preserve the integrity of the steel pressure vessel. The working insert is designed for easy replacement as needed. The removable insert allows users to take advantage of the latest advances in material science in a cost-effective manner.

Purpose/Objectives

The objectives of the proposed work were to

- design a prototype DSPBV
- design the DSPBV support equipment
- demonstrate the operability of the DSPBV
- utilize the successful demonstration to secure additional funding for continued development.

Summary of Activities

The dual shell pressure-balanced reactor vessel (DSPBV) was sized to process 10 gal/hr of hazardous waste at up to 750°F (399°C) and 5000 psia (34.5 MPa) with a residence time of 10 minutes. A stress analysis of the reactor vessel indicated the design has a good safety margin for the chosen operating conditions. The first prototype reactor was purchased by Innotek Corporation and built by Engineered Pressure Systems Inc. (a division of National Forge) in Andover, Massachusetts. It was built as a certified ASME pressure vessel. The vessel dimensions resulting from this design and fabrication activity are shown in Figure 1.

Supporting equipment and instrumentation was identified, and specifications were documented. Preliminary blueprints have been prepared for the complete reactor system. The reactor system was designed as a skid mounted package unit which could be moved to industrial sites after proof-of-principle experiments are completed at PNL.

An internal safety review of the design package was completed by Safety and Quality Assurance staff at PNL.

Reactor Design

The DSPBV selected operating pressure (3500 psia [24.1 MPa]) and temperature (700°F [371°C]) were based on literature references (Shaw et al. 1991 and Dell Orco et al. 1992) for laboratory-scale results of Supercritical Water Oxidation (SCWO). The 10-minute residence time was a compromise based on these reports. Some wastes can be destroyed in a few seconds and others may require 30 minutes. The 10 gal/hr (36 L/hr) was considered sufficient to provide good data for at least a future pilot-scale version of the concept.

The DSPBV uses a thick steel outer shell as the pressure boundary and a thin disposable inner liner which can be made from corrosion resistant alloys appropriate for the chemicals being processed. The shell and the inner liner are separated by heat transfer fluid (used here as a pressure transfer fluid). The pressure between the heat transfer fluid and the reacting fluid is maintained by an external piston that remains at ambient temperature. A pressure compensator is needed because the heat transfer liquid (Syltherm 800®) expands about 65% in volume between ambient and 750°F (399°C).

A second disposable inner liner is used as a flow diverter so reactants enter and products leave the same end of the vessel. The disposable inner liners allow the study of corrosion characteristics of many materials such as Inconel, Hastelloy, zirconium, titanium, titanium-tantalum, or titanium-niobium alloys for a fraction of the cost of building a complete reactor out of these materials. The design is inherently safer than metal clad vessels because sensors in the heat transfer fluid will detect when the corrosion-resistant alloy has been breached. Metal clad vessels have no simple warning system and penetration of the cladding generally results in rapid deterioration of the parent metal.

Figure 2 shows a sketch of the fundamental pieces involved in the pressure balanced piston idea. Other options were studied but rejected for either time or money considerations. These concepts included 1) a bellows, 2) a sliding o-ring seal, and 3) the balancing piston with a stationary o-ring seal (instead of welds used in the final design).

Support Equipment

The supporting equipment (see the Appendix) was grouped into six categories for purposes of designing transportable modules. Secondly the modules grouped equipment to enhance safe operation. The modules were

- the main reactor and pressure balancing piston
- hazardous waste feed supply tanks and pump
- Syltherm supply tanks and pump
- high pressure oxygen supply system
- pressure let-down equipment
- containment vessels.

Optional modules are shown in the Appendix for bottled oxygen and bottled nitrogen. The nitrogen is a purge gas for feed and let-down vessels as well as the containment vessel. The containment equipment is designed to capture all the reactor fluids in the event of an over-pressure, cool them to 150°F or lower, and keep them in a nitrogen purged containment vessel until a final disposal plan is approved. Originally the equipment was designed to handle a variety of wastes. The nitrogen manifold and containment vessels were needed to handle some Department of Defense munitions wastes which can be unstable in the presence of air. Funding is still being sought from the Navy to demonstrate destruction of some of their munitions wastes.

Figure 3 shows schematically a picture of existing equipment that will be used in the follow-on work to prove that the DSPBV really works. Waste materials will be more benign (e.g., sewage sludge effluent) and can be processed using simpler safety controls.

Significant Accomplishments

- A transportable system using the DSPBV has been designed.
- Preliminary blueprints have been developed for the entire system.
- The first prototype reactor vessel has been built and delivered to PNL.
- Support equipment was identified at PNL to perform initial testing.
- Follow-on funding has been obtained to test the reactor vessel.

Significant Problems

Funding levels were insufficient to build the transportable system designed in this effort. Using existing equipment will limit the range of conditions which can be investigated.

Industry Benefits Realized

This collaborative research program succeeded in building the first prototype Dual Shell Pressure Balanced Vessel. We believe the concept can be commercially successful on a larger scale and can be

fabricated much less expensively than current practice. Simultaneously the concept can enhance safety and operability of many emerging high pressure chemical processes.

The adoption and commercialization of a broad range of new high pressure chemical technologies will be enhanced by the development of the DSPBV. **The** potential market for this vessel is far reaching particularly in environmental management. Specific technologies include supercritical fluid extraction or oxidation, wet air oxidation, hydrothermal materials processing, and sewage sludge to oil conversion.

Follow-on Work

The design and fabrication of the first DSPBV have led to funding from DOE's Environmental Management office to conduct the proof-of-principle experiments in its SCWO program.

A spin-off CRADA has also been funded to help perfect the leak detector design which is a critical part of the safety instrumentation. **Innotek** is a participating partner in both activities.

Existing hydrothermal equipment at PNL will be modified and used to conduct the proof-of-principle tests for the SCWO program.

Testing of this unit will bridge the gap between science in the laboratory and private industry utilization.

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Figure 1. Sketch of Dual Shell Pressure Balanced Vessel

Figure 2. Reactor Vessel with Pressure Balancing Piston

Figure 3. Dual Shell Reactor and Support Equipment

Appendix

**Preliminary Equipment List and Drawings
for
Dual Shell Pressure Balanced Vessel
and
Supporting Equipment**

Appendix

**Preliminary Equipment List and Drawings
for
Dual Shell Pressure Balanced Vessel
and
Supporting Equipment**

This equipment list and these drawings are preliminary in that they have not been checked for errors, and have no formal **PNL** approvals. They are not approved for construction of a complete reactor system. The equipment list is unfinished in terms of identifying all model numbers but is believed to be fairly complete otherwise. Identifying items in the table with those on the drawings is unfinished work.

DOUBLE SHELL REACTOR - Preliminary Parts List				
	Type	Brand	Model	Comments
Syltherm Components				
10 Gal Tank			Stainless Steel	
Welded fitting		Swagelok	SS-400-6-4W	
Tubing	1 1/4"		Stainless Steel	
V1 - with 114 Swagelok	ball	Whitey	SS-43S4-BK	teflon seals
Tubing	1 1/4"		Stainless Steel	
Filter		Nupro	SS-4TF-140	
Tubing	1 1/4"		Stainless Steel	
Fitting: tube - 3/8 (M)		Swagelok	SS-400-1-6	
Centrifugal pump		Cole-Parmer	L-07021-01	5 gpm 13 ft hd 3/8 NPT F inlet
Fitting: tube - 114 (F)		Swagelok	SS-400-7-4	
Tubing	1 1/4"		Stainless Steel	
V2 with 114 Swagelok	check	Nupro	SS-CHS4-5	teflon seals
Tubing	1 1/4"		Stainless Steel	
V3 with 114 Swagelok	needle	Whitey	SS-3HNTRS4-440C	teflon seals
Tubing	1 1/4"		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	
Pressure Transducer		Yokogawa	YA53-SHS3*A	
Fitting:		Swagelok	SS-400-1-4	
Tubing	1 1/4"		Stainless Steel	
Fitting: (M) connector		Swagelok	SS-400-1-1	to reactor
Fitting: (M) connector		Swagelok	SS-400-1-1	from reactor
Tubing	1 1/4"		Stainless Steel	
V4 with 114 Swagelok	needle	Whitey	SS-3HNTRS4-440C	teflon seals
Tubing	1 1/4"		Stainless Steel	return line to drum
Fitting: (M) connector		Swagelok	SS-400-1-1	drum tilting
SYL THERM PRESSURE RELIEF SYS.				
Fitting: (M) connector		Swagelok		from reactor to relief vessel
Tubing	1 1/2"		Stainless Steel	
Fitting: Union Tee		Swagelok		
Tubing	1 1/2"		Stainless Steel	
Fitting:		Swagelok		to accumulator
Accumulator		Haskel	15801-2	
Tubing	1 1/2"		Stainless Steel	from Tee to relief vessel
Fitting:		Swagelok		
Pressure Transducer		Yokogawa	YA53-SHS3*A	
Fitting:		Swagelok		
Tubing	1 1/2"		Stainless Steel	
Fitting:		Swagelok		
Rupture Disk	rupture disk	Fike	1/2-100SB-13	6300 max
Fitting:		Swagelok		
Tubing	1 1/2"		Stainless Steel	
Fitting:		Swagelok		Enter heat exch.
Core Tubing	1 1/2"		Stainless Steel	
Fitting:		Swagelok		Exit heat exch.
Tubing	1 1/2"		Stainless Steel	
Fitting:		Swagelok		To relief vessel
Cooling water tubing	1"		Stainless Steel	
Fitting: Union Tee		Swagelok	SS-1610-3	
Tubing	1"		Stainless Steel	
Solenoid Valve		Swagelok	SS-33V54-310D	
Tubing	1"		Stainless Steel	
Fitting: Union Tee		Swagelok	SS-1610-3	
Tubing	1"		Stainless Steel	
Fitting		Swagelok	SS-1610-1-12	
Throttling Valve		Whitey	SS-26VM12-F8	

Fitting		Swagelok	SS-1610-1-16	
Tubing	1"		Stainless Steel	
Fitting: Male Connector		Swagelok	SS-1610-1-16	Cooling H2O enters
Exchanger Shell		Fabricated		
Fitting: Male Connector		Swagelok	SS-1610-1-16	Cooling H2O exits
Tubing	1"		Stainless Steel	
Throttling Valve		Swagelok		
Sight Drain		Ernst Gage	E-57-SS-4	
Cooling water tubing	1"		Stainless Steel	
Tubing	1/4"		Stainless Steel	
Thermocouple fitting		Swagelok	SS-200-R-4-BT	
Thermocouple	Type K	Omega	TJ36-CAIN-18G-??	Purchase quick disconnect plugs
Organic Liquid Waste Components				
50 Gal Tank			Stainless Steel	
Welded fitting		Swagelok	SS-400-6-4W	
Tubing	1/2"		Stainless Steel	
Fitting		Swagelok		
Filter		McMaster	4745K9	
Fitting		Swagelok		
V6 - with 1/4 Swagelok	ball	Whitey	SS-45S8-BK	
Tubing	1/2"		Stainless Steel	
Fitting: Reducer 1/4 - 1/2		Swagelok	SS-400-R-8-BT	
Fitting: Union Tee		Swagelok	SS-810-3	
Thermocouple	Type K	Omega	TJ36-CAIN-14G-??	Purchase quick disconnect plugs
Tubing	1/2"		Stainless Steel	
V7 - with 1/4 Swagelok	check	Nupro	SS-8C-1	
Tubing	1/2"		Stainless Steel	
Fitting:		Swagelok	SS-810-1-8	
Liquid Pump	pneumatic	Haskel	AW-60-C	
Fitting:		Swagelok	SS-810-1-8	SS-400-1-8 for 1/4 tubing
Tubing	1/2"		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	
High press. accumulator		Haskel	15801-2	
Fitting:		Swagelok	SS-400-1-4	
Tubing	1/4"		Stainless Steel	
V8 - with 1/4 Swagelok	needle	Whitey	SS-3HNTRS4-440C	
Tubing	1/4"		Stainless Steel	
Fitting: Reducer 1/16 - 1/4		Swagelok	SS-100-R-4-BT	
Fitting: Union Tee		Swagelok	SS-400-3	
Thermocouple	Type K	Omega	TJ36-CAIN-116G-??	Purchase quick disconnect plugs
Tubing	1/4"		Stainless Steel	
Fitting:		Swagelok	SS-810-6-4 + SS-810-A-8ANF	
Flow Sensor		Omega	FTB502-1CK-5KP	.025-.25 GPM
Fitting:		Swagelok	SS-810-6-4 + SS-810-A-8ANF	
Tubing	1/4"		Stainless Steel	
Fitting: (F) Branch Tee		Swagelok	SS-400-3-4TTF	
Tubing	1/4"		Stainless Steel	
Fitting:		Swagelok		
rupture disk		Fike	1/2-100SB-13	6300 max
Fitting:				
Tubing	1/4"		Stainless Steel	to relief vessel
Fitting:		Swagelok	SS-400-1-4	Enter heat exch.
Core Tubing	1/4"		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	Exit heat exch.
Tubing	1/4"		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	To relief vessel
Cooling water tubing	1"		Stainless Steel	
Fitting: Union Tee		Swagelok	SS-1610-3	
Tubing	1"		Stainless Steel	
Solenoid Valve		Swagelok	SS-33V54-310D	

Tubing	1"		Stainless Steel	
Fitting: Union Tee		Swagelok	SS-1610-3	
Tubing	1"		Stainless Steel	
Fitting		Swagelok	SS-1610-1-12	
Throttling Valve		Whitey	SS-26VM12-F8	
Fitting		Swagelok	SS-1610-1-16	
Tubing	1"		Stainless Steel	
Fitting: Male Connector		Swagelok	SS-1610-1-16	Cooling H2O enters
Exchanger Shell		Fabricated		
Fitting: Male Connector		Swagelok	SS-1610-1-16	Cooling H2O exits
Tubing	1"		Stainless Steel	
Throttling Valve				
Sight Drain				
Cooling water tubing	1"		Stainless Steel	
Tubing	1/4"		Stainless Steel	
Thermocouple fitting		Swagelok	SS-200-4-BT	
Thermocouple	Type K	Omega	TJ36-CAIN-18G-??	Purchase quick disconnect plugs
Tubing	1/4"		Stainless Steel	From Union Tee before rupture disk
Fitting: (F) Branch Tee		Swagelok	SS-400-3-4TTF	
Tubing	1/4"		Stainless Steel	to lecture bottle then accumulator
Fitting		Swagelok	SS-400-1-4	
Lecture Bottle		Fabricate		
Fitting		Swagelok	SS-400-1-4	
Tubing	1/4"		Stainless Steel	
Fitting		Swagelok		to accumulator
Tubing	1/4"		Stainless Steel	From union tee
Fitting:		Swagelok	SS-400-1-4	
Pressure Transducer		Yokogawa	YA53-SHS3*A	
Fitting		Swagelok	SS-400-1-4	
Tubing	1/4"		Stainless Steel	
Fining: (M) connector		Swagelok	SS-400-1-1	to reactor
Relief Vessel Components				
Vessel			Skinless Steel	
N2 purge tubing	1/4"		Stainless Steel	Pressurizing line
Check Valve				
Tubing	1/4"		Stainless Steel	
Fitting				To vessel
Fitting				From vessel
Tubing	1/4"		Skinless Steel	Purge line
Check Valve				
Tubing	1/4"		Skinless Steel	
Tubing	2"		Stainless Steel	Flush out line (in)
Ball Valve				
Tubing	2"		Stainless Steel	
Fitting				To vessel
Fitting				Flush out line from vessel
Tubing	2"		Stainless Steel	
Ball Valve				
Tubing	2"		Stainless Steel	
Fitting				Flush out line from vessel
Tubing	2"		Stainless Steel	
Relief Valve				
Tubing	2"		Stainless Steel	
Oxygen Components				
Standard Oxygen Bottles		From Stores		
Single regulator 2 header	Manifold	Rexarc	3-04-431G/12	12 bottles of O2
Fitting		Swagelok		

Tubing			Stainless Steel	
Fitting				
Flow Sensor		Sierra	830-H-2-(10 SCFM)-V1-C2	
Fitting				
Tubing			Stainless Steel	
Fitting		Swagelok	SS-400-1-4	
Oxygen Booster		Haskel	59784	
Fitting		Swagelok	SS-400-1-4	
Tubing			Stainless Steel	
Fitting		Swagelok	SS-400-1-4	
Valve	ball	Tescom	30-1100204	
Fitting		Swagelok	SS-400-1-4	
Tubing			Stainless Steel	
Fitting: Reducer 1116 - 1/4		Swagelok	SS-100-R-4-BT	
Fitting: Union Tee		Swagelok	SS-400-3	
Thermocouple	Type K	Omega	TJ36-CAIN-116G-??	Purchase quick disconnect plugs
Tubing	1/4"		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	
Pressure Transducer		Yokogawa	YA53-SHS3*A	
Fitting: Tee Union		Swagelok	SS-400-3	
Tubing			Stainless Steel	
Fitting				
Solenoid Valve		Swagelok	SS-33V54-310D	
Fitting				
Tubing			Stainless Steel	
Fire Arresting Check Valve		Nupro	SS-53S4	
Tubing			Stainless Steel	
Fire Arresting Check Valve		Nupro	SS-53S4	
Tubing			Stainless Steel	
Fire Arresting Check Valve		Nupro	SS-53S4	
Tubing			Stainless Steel	
Fitting		Swagelok	SS-100-1-1ET	To Reactor
Compressed Air Components				
Compressor		Ingersoll		100 hp 460 - 3 phase
Tubing	1"		Stainless Steel	
Fitting		Swagelok		
Solenoid Valve		Swagelok	SS-33V54-310D	
Fitting		Swagelok		
Tubing	1"		Stainless Steel	
Fitting: Union*		Swagelok	SS-1610-3	
Tubing	1"		Stainless Steel	
Fitting:		Swagelok	SS-1610-1-8	
Regulator		Tescom	26-1022-28	
alternative regulator		Tescom	441312-2081-005	check Cv
Gage		Tescom	4370-0600N	
Gage		Tescom	4370-0600N	
Fitting:		Swagelok	SS-1610-1-8	
Tubing	1"		Stainless Steel	
Fitting:		Stainless Steel	SS-1610-1-12	To 0.2 booster
Fitting*		Swagelok	SS-1610-1-8	0.2 booster exhaust
Tubing	1"		Stainless Steel	To exhaust
Tubing	1"		Stainless Steel	From union tee fitting
Fitting:		Swagelok	SS-1610-1-8	
Regulator		Tescom	26-1022-28	
alternative regulator		Tescom	441312-2081-005	check Cv
Gage		Tescom	4370-0600N	
Gage		Tescom	4370-0600N	
Fitting:		Swagelok	SS-1610-1-8	
Tubing	1"		Stainless Steel	
Fitting:		Swagelok	SS-1610-1-8	To liquid pump

Fitting:		Swagelok	SS-1610-1-8	Liquid pump exhaust
Tubing:	1 "		Stainless Steel	To exhaust
Reactor Product Components			54-2100 series	
Fitting: (M) connector		Swagelok	SS-400-1-1	From reactor
Tubing	1 1/4 "		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	Enter heat exch.
Cote Tubing	1 1/4 "		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	Exit head exch
Cooling water tubing	1 "		Stainless Steel	
Ball Valve		Swagelok	SS-65IS16	
Fitting:				
Optical Flow Meter				
Fitting:				
Fitting: Male Connector		Swagelok	SS-1610-1-16	Cooling H2O enters
Exchanger Shell		Fabricated		
Fitting: Male Connector		Swagelok	SS-1610-1-16	Cooling H2O exits
Cooling water tubing	1 "		Stainless Steel	
Fitting:				
Throttling Valve		Swagelok		
Fitting:				
Tubing			Stainless Steel	
Sight Drain				
Tubing	1 1/4 "		Stainless Steel	
Fitting:		Swagelok	SS-400--61	Enter heat exch.
Core Tubing	1 1/4 "		Stainless Steel	
Fitting		Swagelok	SS-400-1-4	Exit head exch
Cooling water tubing	1 "		Stainless Steel	
Fitting:				
Ball Valve				
Fitting:				
Optical Flow Meter				
Fitting:				
Fitting: Male Connector		Swagelok	SS-1610-1-16	Cooling H2O enters
Exchanger Shell		Fabricated		
Fitting: Male Connector		Swagelok	SS-1610-1-16	Cooling H2O exits
Cooling water tubing	1 "		Stainless Steel	
Tubing	1 1/4 "		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	Enter heat exch
Core Tubing	1 1/4 "		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	Exit head exch.
Cooling water tubing	1 "			
Fitting:				
Ball Valve				
Fitting:				
Optical Flow Meter				
Fitting:				
Fitting:				
Ball Valve				
Fitting:				
Optkal Flow Meter				
Fitting:				
Fitting: Male Connector		Swagelok	SS-1610-1-16	Cooling H2O enters
Exchanger Shell		Fabricate		
Fitting: Male Connector		Swagelok	SS-1610-1-16	Cooling H2O exits
Cooling water tubing	1 "		Stainless Steel	
Fitting:				
Ball Valve				
Fitting:				
Optical Flow Meter				
Fitting:				

Tubing	1/4"		Stainless Steel	
Fitting: Reducer 1116 - 1/4		Swagelok	SS-100-R-4-BT	
Filling: Union Tee		Swagelok	SS-400-3	
Thermocouple	Type K	Omega	TJ36-CAIN-116G-??	Purchase quick disconnect plugs
Tubing	114"		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	
Pressure Transducer		Yokogawa	YA53-SHS3*A	
Fitting:		Swagelok	SS-400-1-4	
V18	back press.	Tescom	54-2325T212A	150F 5000 psi
Fitting: Male Connector		Swagelok	SS-400-1-12	
Tubing	114"		Stainless Steel	
Fitting:				
Seperation Bottle		Eabricated	Stainless Steel	
Pressure relief valve	press relief	Nupro	SS-4R3A1-B	teflon seals
Tubing to vent	114"		Stainless Steel	
Fitting:				
Tubing	114"		Stainless Steel	
Fitting: Reducer 1116 - 1/4		Swagelok	SS-100-R-4-BT	
Filling: Union Tee		Swagelok	SS-400-3	
Thermocouple	Type K	Omega	TJ36-CAIN-116G-??	Purchase quick disconnect plugs
Tubing	114"		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	
Flow Sensor		Sierra	760-N1	
Fitting:		Swagelok	SS-400-1-4	
Tubing	114"		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	
Pressure Transducer		Yokogawa	YA53-SHS3*A	
Fitting:		Swagelok	SS-400-1-4	
Tubing	114"		Stainless Steel	
Fitting: Union Tee		Swagelok	SS-400-3	
Tubing	114"		Stainless Steel	
V19 - with 114 Swagelok	ball	Whitey	SS-43S4	
Tubing	114"		Stainless Steel	
Fitting:				To vent
Tubing	114"		Stainless Steel	
V19 - with 1/4 Swageiok	ball	Whitey	SS-43S4	
Tubing	114"		Stainless Steel	
Fitting:				
Filter				
Fitting:				
Tubing	114"		Stainless Steel	
Filling:				To GC
Fitting:				
Tubing	114"		Stainless Steel	
Fitting: Reducer 1/16 - 1/4		Swagelok	SS-100-R-4-BT	
Fitting: Union Tee		Swagelok	SS-400-3	
Thermocouple	Type K	Omega	TJ36-CAIN-116G-??	Purchase quick disconnect plugs
Tubing	114"		Stainless Steel	
Fitting:		SS	SS-400-1-8	
Flow Sensor		Sierra	730-N2-2-901M	
Fitting:		Swagelok	SS-400-1-8	
Tubing	1/4"		Stainless Steel	
Fitting:		Swagelok	SS-400-1-4	
Pressure Transducer		Yokogawa	YA53-SHS3*A	
Fitting:		Swagelok	SS-400-1-4	
Tubing			Stainless Steel	
Fitting: Union Tee		Swagelok	SS-400-3	
Tubing	114"		Stainless Steel	
V19 - with 114 Swagelok	ball	Whitey	SS-43S4	
Tubing	114"		Stainless Steel	

Fitting:				to drain
Tubing	1 1/4"		Stainless Steel	
V19 - with 1 1/4 Swagelok	ball	Whitey	SS-43S4	
Tubing	1 1/4"		Stainless Steel	
Fitting:				
Filter				
Fitting:				
Tubing	1 1/4"		Stainless Steel	
Fitting:				to sampler

NOTES

1. ALL MATERIALS AND EQUIPMENT TO BE AS SPECIFIED OR AN ENGINEER APPROVED EQUAL.
2. TUBING SHALL BE AS SPECIFIED:
1/2" OD X .063 WALL, 304 SST, ASTM A269, SEAMLESS
1/4" OD X .063 WALL, 304 SST, ASTM A269, SEAMLESS
3. ALL TUBE FITTINGS SHALL BE SWAGelok, SST OR AN ENGINEER APPROVED EQUAL. NO FEMALE CONNECTORS ALLOWED.
4. DESIGN PRESSURE = 5000 PSI
DESIGN TEMPERATURE = 750° F
OPERATING PRESSURE = 3500 PSI
OPERATING TEMPERATURE = 600° F
5. TUBE ROUTING AND EQUIPMENT ORIENTATION SHOWN ARE DIAGRAMATIC AND MAY CHANGE AS CONDITIONS WARRANT.
6. FABRICATOR SHALL BE RESPONSIBLE FOR SUPPORTING TUBING AND EQUIPMENT PER MANUFACTURERS AND OPERATING ENGINEERS RECOMMENDATIONS.
7. TUBING AND EQUIPMENT SHALL BE CLEANED PER SPECIFICATION #XXXX.

2 PRELIMINARY
NOT APPROVED FOR CONSTRUCTION

CONCEPTUAL

DRAWN: MA COVERT		DATE: 1-2-81		U. S. DEPARTMENT OF ENERGY	
CHECKED: [blank]		DATE: [blank]		PACIFIC NORTHWEST LABORATORY	
DESIGNED: [blank]		DATE: [blank]		OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
ENGR: RJ ROBERTUS		DATE: [blank]		DOUBLE SHELL REACTOR	
APPROVED: [blank]		DATE: [blank]		PROCESS LAYOUT	
OTHER: [blank]		DATE: [blank]		CONCEPT	
APPROVED FOR IMPLEMENTATION: [blank]		DATE: [blank]		DSR-003.0	
BY: [blank]		DATE: [blank]		SCALE: 1/8"	
FOR: [blank]		DATE: [blank]		SHEET 1 OF 1	

REV	DATE	DESCRIPTION	BY	CHKD	APPD
1	1-2-81	CONCEPT	MA COVERT		
2	1-2-81	CONCEPT	MA COVERT		
3	1-2-81	CONCEPT	MA COVERT		
4	1-2-81	CONCEPT	MA COVERT		
5	1-2-81	CONCEPT	MA COVERT		
6	1-2-81	CONCEPT	MA COVERT		
7	1-2-81	CONCEPT	MA COVERT		
8	1-2-81	CONCEPT	MA COVERT		
9	1-2-81	CONCEPT	MA COVERT		
10	1-2-81	CONCEPT	MA COVERT		
11	1-2-81	CONCEPT	MA COVERT		
12	1-2-81	CONCEPT	MA COVERT		
13	1-2-81	CONCEPT	MA COVERT

NOTES

- ALL MATERIALS AND EQUIPMENT TO BE AS SPECIFIED OR AN ENGINEER APPROVED EQUAL.
- TUBING SHALL BE AS SPECIFIED:
1/4" OD X .085 WALL, 304 ST, ASTM A269, SEAMLESS.
1" OD X .083 WALL, 304 SST, ASTM A269, SEAMLESS.
- ALL TUBE FITTINGS SHALL BE SWAGelok, SST OR AN ENGINEER APPROVED EQUAL. NO FEMALE CONNECTORS ALLOWED.
- DESIGN PRESSURE = 5000 PSI
DESIGN TEMPERATURE = 750° F
OPERATING PRESSURE = 3500 PSI
OPERATING TEMPERATURE = 600° F
- CHANGEOVER/SHUTDOWN/EQUIPMENT ORIENTATION SHOWN ARE DIAGRAMATIC AND MAY VARY.
- FABRICATOR SHALL BE RESPONSIBLE FOR SUPPORTING TUBING AND EQUIPMENT PER MANUFACTURERS AND OPERATING ENGINEERS RECOMMENDATIONS.
- TUBING AND EQUIPMENT SHALL BE CLEANED PER SPECIFICATION #XXXX.

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CONCEPTUAL

2 PRELIMINARY

NOT APPROVED FOR CONSTRUCTION

REV	DATE	DESCRIPTION
1	10/1/83	ISSUED FOR CONSTRUCTION
2	10/1/83	ISSUED FOR CONSTRUCTION
3	10/1/83	ISSUED FOR CONSTRUCTION
4	10/1/83	ISSUED FOR CONSTRUCTION
5	10/1/83	ISSUED FOR CONSTRUCTION
6	10/1/83	ISSUED FOR CONSTRUCTION
7	10/1/83	ISSUED FOR CONSTRUCTION
8	10/1/83	ISSUED FOR CONSTRUCTION
9	10/1/83	ISSUED FOR CONSTRUCTION
10	10/1/83	ISSUED FOR CONSTRUCTION
11	10/1/83	ISSUED FOR CONSTRUCTION
12	10/1/83	ISSUED FOR CONSTRUCTION
13	10/1/83	ISSUED FOR CONSTRUCTION

PACIFIC NORTHWEST LABORATORY OPERATED BY BATTELLE MEMORIAL INSTITUTE	
DOUBLE SHELL REACTOR ENDLAYOUT CONCEPT	
DESIGNED BY R.J. ROBERTUS	DATE 10/1/83
CHECKED BY R.J. ROBERTUS	DATE 10/1/83
APPROVED FOR CONSTRUCTION BY TOP	DATE 10/1/83
SCALE 1/8"	
SHEET 1 OF 1	

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NOTES

1. ALL MATERIALS AND EQUIPMENT TO BE AS SPECIFIED OR AN ENGINEER APPROVED EQUAL.
2. TUBING SHALL BE AS SPECIFIED:
1/2" OD X .083 WALL, 304 SST, ASTM A269, SEAMLESS.
1" OD X .083 WALL, 304 SST, ASTM A269, SEAMLESS.
3. ALL TUBE FITTINGS SHALL BE SWAGelok, SST OR AN ENGINEER APPROVED EQUAL. NO FEMALE CONNECTORS ALLOWED.
4. DESIGN PRESSURE = 5000 PSI
DESIGN TEMPERATURE = 7 M F
OPERATING PRESSURE = 3500 PSI
OPERATING TEMPERATURE = 600 F
5. TUBE ROUTING AND EQUIPMENT ORIENTATION SHOWN ARE DIAGRAMATIC AND MAY CHANGE AS CONDITIONS WARRANT.
6. FABRICATOR SHALL BE RESPONSIBLE FOR SUPPORTING TUBING AND EQUIPMENT PER MANUFACTURERS AND OPERATING ENGINEERS RECOMMENDATIONS.
7. TUBING AND EQUIPMENT SHALL BE CLEANED PER SPECIFICATION #X000.

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4-15
83
PRELIMINARY
NOT APPROVED FOR CONSTRUCTION

CONCEPTUAL

DRAWING NO. DSR-005		DATE 3-8-83		U. S. DEPARTMENT OF ENERGY PACIFIC NORTHWEST LABORATORY OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
DRAWING TITLE DOUBLE SHELL REACTOR RELIEF VESSEL CONCEPT		DESIGNED BY RJ ROBERTUS		CHECKED BY RJ ROBERTUS	
APPROVED FOR CONSTRUCTION		APPROVED FOR CONSTRUCTION		APPROVED FOR CONSTRUCTION	
NEXT USED ON		REVISIONS		SCALE 1/8"	
DRAWING NO.		DRAWING TITLE		DRAWING NO.	
DRAWING NO.		DRAWING TITLE		DRAWING NO.

NOTES

1. ALL MATERIALS AND EQUIPMENT TO BE AS SPECIFIED OR AN ENGINEER APPROVED EQUAL.
2. TUBING SHALL BE AS SPECIFIED:
1/4" OD X .085 WALL, 304 SST, ASTM A269, SEAMLESS.
1/2" OD X .083 WALL, 304 SST, ASTM A269, SEAMLESS.
3. ALL TUBE FITTINGS SHALL BE SWAGelok, SST OR AN ENGINEER APPROVED EQUAL. NO FEMALE CONNECTORS ALLOWED.
4. DESIGN PRESSURE = 5000 PSI
DESIGN TEMPERATURE = 750° F
OPERATING PRESSURE = 3500 PSI
OPERATING TEMPERATURE = 600° F
5. TUBE ROUTING AND EQUIPMENT ORIENTATION SHOWN ARE DIAGRAMATIC AND MAY CHANGE AS CONDITIONS WARRANT.
6. FABRICATOR SHALL BE RESPONSIBLE FOR SUPPORTING TUBING AND EQUIPMENT PER MANUFACTURERS AND OPERATING ENGINEERS RECOMMENDATIONS.
7. TUBING AND EQUIPMENT SHALL BE CLEANED PER SPECIFICATION #XXXX.

2
PRELIMINARY

NOT APPROVED FOR CONSTRUCTION

CONCEPTUAL

DRAWN BY: MA COVERT		DATE: 1/1/81		U. S. DEPARTMENT OF ENERGY	
DTS: APD		ENGR: RJ ROBERTUS		PACIFIC NORTHWEST LABORATORY OPERATED BY BATTELLE MEMORIAL INSTITUTE	
APD		OTHER:		DOUBLE SHELL REACTOR REACTOR COMPONENTS CONCEPT	
APPROVED FOR IMPLEMENTATION:		DATE: 1/1/81		DSR-006 0	
BY: FOR: DATE:		SCALE: 1/8		SHEET 1 OF 1	

REV	NO	DATE	DESCRIPTION
1	1	1/1/81	ISSUED FOR CONSTRUCTION

DRWING NO	DRWING TITLE	REVISIONS
DSR-006	DOUBLE SHELL REACTOR	1/1/81
NEXT USED ON		

13 12 11 10 9 8 7 6 5 4 3 2 1 A-13

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PRELIMINARY

NOT APPROVED FOR CONSTRUCTION

CONCEPTUAL

U. S. DEPARTMENT OF ENERGY
 RICHLAND OPERATIONS OFFICE
 PACIFIC NORTHWEST LABORATORY
 OPERATED BY BATTELLE MEMORIAL INSTITUTE

VESEL CONCEPT

DSR-009 0

SCALE 1/2

SHEET 1 OF 1

A-14

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PRELIMINARY

NOT APPROVED FOR CONSTRUCTION

CONCEPTUAL

DRAWING NO		DRAWING TITLE		RR	MF	QA	BY	DATE	ENGR	BY	DATE	CHE	BY	DATE	REV	BY	DATE	DESCRIPTION	NO	BY	DATE						
NEXT USED ON		REFERENCE DRAWINGS		REVISIONS																CAO CODE		CAO FILE		APPROVED FOR IMPLEMENTATION		DATE	
U. S. DEPARTMENT OF ENERGY		RICHLAND OPERATIONS OFFICE		PACIFIC NORTHWEST LABORATORY																OPERATED BY OAKVILLE MEMORIAL INSTITUTE		VESSEL CONCEPT		DSR-010		0	
SCALE 1/4		SHEET 1 OF 1		A-15

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4-18
83 PRELIMINARY
NOT APPROVED FOR CONSTRUCTION

CONCEPTUAL

[illegible]

QTY	PN	DESCRIPTION	MATL/REF
X	1	ASSEMBLY	
1	2	SHELL WELDMENT	SHEET 2
1	3	TUBE COIL	SHEET 2
1	4	UPPER FLANGE	SHEET 2
1	5	LOWER FLANGE #35-400-1-8BT	SWAGELLON
1	6	SO HEAD PIPE PLUG, 1/2 NPT	ASTM A 182 GR F 304L
1	7	FLANGE GASKET, 1/16" THK, FOR PN 4	PTFE (TEFLON OR EQUAL)
8	8	HEX BOLT, 5/8-11UNC-2A X 3"L	ASTM A 193 GR B8 304
8	9	HEX NUT, 5/8-11UNC-2B	ASTM A 194 GR CF 303

U. S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
PACIFIC NORTHWEST LABORATORY
OPERATED BY BATTELLE MEMORIAL INSTITUTE

HEAT EXCHANGER
ASSEMBLY
CONCEPT

DSR-0110

1 OF 2