DESIGN CRITERIA FOR
 PHASE II DUMMY HYDRAULIC CORE
 FOR CONTAINMENT SYSTEMS EXPERIMENT
 REACTOR SIMULATOR

October 3, 1966

Prepared by Battelle-Northwest
 Engineering Development

NOTICE
 This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

C. H. Henager
 Prepared by

10-3-66
 Date

Approved for Battelle-Northwest:

P. Walburn
 Engineering Development

10-5-66
 Date

J. Rogers
 Experimental Reactor Safeguards

10-7-66
 Date

MASTER

EX-103
 CONTRACT NO. E(45-1)-1830

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DESIGN CRITERIA FOR
PHASE II DUMMY HYDRAULIC CORE
FOR CONTAINMENT SYSTEMS EXPERIMENT
REACTOR SIMULATOR

1.0 SCOPE

This criteria covers design of a Phase II dummy hydraulic core for the CSE reactor simulator. The core will be a scale model having features typical of PWR or BWR reactor cores, and will include control rods and associated support mechanisms, fuel elements, a thermal shield, top and bottom core guide and support plates, and flow baffles. The core and simulator vessel will be instrumented to provide measurement of temperature, static and differential pressures, forces on core components, and rarefaction wave pressures during high temperature, high pressure blowdown studies.

2.0 REFERENCE DRAWINGS AND DOCUMENTS

2.1 Drawings

Struthers Wells Corp. Drawings

2.1.1 64-2-2222 D1 Rev. 1, Setting Plan for Reactor Simulator Vessel

2.1.2 64-2-2222 D2 Rev. 1, Shell Details for Reactor Simulator Vessel

2.1.3 64-2-2222 D3 Rev. 1, Head Detail for Reactor Simulator Vessel

The above drawings form book 5 of 5, "Pressure Part Design Drawings," of the ASME Boiler and Pressure Vessel Code Section III Stress Report for the Reactor Simulator Vessel, by Lessells and Associates, Technical Report 893-5. Revised December 3, 1965.

RL00 Drawings

2.1.4 H-2-32788 Control Panel Arrangement and Details

H-2-32602 Engr. Flow Diagram-Simulator Heating Loop

H-2-33153 Plot Plans and Details

H-2-33154 Architectural-Structural Plan, Sections and Details

H-2-33155 Foundation Plan - Simulator Vessel Mockup

- H-2-33156 Floor Plan - Simulator Vessel Mockup
- H-2-33157 Plans and Elevation-Simulator Support Tower
- H-2-33172 Lighting Plan and Elevations

2.2 Documents

- 2.2.1 HWS-7247 Rev. 1, Specification for Procurement of Reactor Simulator Vessel.
- 2.2.2 Technical Reports 893-1 through 893-5, "Reactor Simulator Vessel, ASME Boiler and Pressure Vessel Code Section III Stress Report (Books 1 through 5), Lessells and Associates.
- 2.2.3 BNWL-26, "Instrumentation Development for the Containment Systems Experiment," February 3, 1965.
- 2.2.4 BNWL-CC-703, "Design Criteria for Phase I Dummy Hydraulic Core for Containment Systems Experiment Reactor Simulator," June 14, 1966.
- 2.2.5 "Humboldt Bay & Big Rock Point Design and Construction Practice," Power Reactor Technology, Vol. 7, No. 1, Winter 1963-1964.
- 2.2.6 "Consolidated Edison Nuclear Steam Generating Station Design Practice," Power Reactor Technology, Vol. 6, No. 3, June 1963.
- 2.2.7 "The Elk River Reactor Design Practice," Power Reactor Technology, Vol. 5, No. 2, March 1962.
- 2.2.8 "Design Practice: Yankee Nuclear Power Station," Power Reactor Technology, Vol. 2, No. 4, June 1961.
- 2.2.9 "The Dresden Nuclear Power Station," Power Reactor Technology, Vol. 6, No. 2, March 1963.

3.0 Description of the Facility

The reactor simulator is a class A pressure vessel in accordance with the ASME Nuclear Code, Section III, designed for 2750 psig and 600 F. It is to be located at 221-T Building, 200 W area. For the initial series of

blowdown studies it will be located in the 277-T Building. At a later date it will be installed inside the CSE containment vessels for further studies of pressure-temperature transients resulting from blowdown in various representative containment systems.

As described in HWS-7247, blowdown studies will be performed at pressures up to 2500 psig and temperatures up to 600 F. The purpose of the Phase II dummy core is to determine blowdown rates and the magnitude of differential pressures across a reactor core as a result of loss of coolant, and to determine forces from rarefaction waves during the first few hundred milliseconds after the start of blowdown. Other effects to be observed include mechanical damage to the core structure and components and other internals such as flow baffles, emergency cooling headers, steam separators.

Data obtained during Phase II experiments will be compared to calculated results to determine how closely mathematical blowdown models predict actual results.

4.0 Core Requirements

4.1 Basic Parameters

The Phase II dummy core shall be a scale model having features typical of PWR or BWR reactor cores, similar to that shown on the sketches attached.

The following parametric limits shall be applied to the core design:

	<u>From</u>	<u>To</u>	<u>Sketch 1*</u>
(1) Fuel Rod L/D	150	350	288
(2) <u>Coolant Channel Length</u>	800	1200	915
Coolant Channel Minimum Width			

*The numbers in this column represent average numbers obtained by comparison of the respective parameters of five existing BWR and PWR reactor cores.

	(From)	(To)	(Sketch 1)
(3) Fuel Rod Dia., in.	.120	.180	.1562
(4) Fuel Rods/Element	64	256	144
(5) Fuel Elements/Core	70	150	104*
(6) <u>Core Cross Section</u> Vessel Cross Section	.400	.650	.519
(7) <u>Cross Section of Solids in Vessel</u> Vessel Cross Section	.250	.550	.334
(8) No. of Control Rods (to be determined from no. of fuel elements)			30
(9) Thermal Shield Thickness, in.	.25	1.00	.50
(10) Spacing between Thermal Shield O.D. and Vessel I.D., in.			1.0
(11) <u>Fuel Element Length</u> Vessel Length	.205	.265	.221
(12) <u>Element Flow Cross Section</u> Element Cross Section	.475	.665	.500
(13) <u>Control Rod Thickness</u> Element Width	.0350	.0850	.0505
(14) Thermal Shield			
I.D., in.	37	40	39
O.D., in.	38	41	40
(15) Fuel Element Shroud Outside Dimension, in.	2.0	4.5	2.478
(16) Fuel Element Shroud Thickness, in.	.016	.062	.031
(17) Control Rod Thickness, in.	.0625	.250	.125
(18) Control Rod Width, in.	1.75	8.50	4.750

4.2 Simulated Flow Circuit

The core shall be designed to simulate a definite flow circuit, even though no large circulating system will be used. The simulated primary

*100 since center 4 elements are deleted for level probe installation.

coolant flow circuit shall enter the lower blowdown nozzles, pass through a flow distributing baffle and make a single pass through the reactor. Flow passages shall be provided so that approximately 8% of coolant flow would be directed between the thermal shield and the vessel wall and approximately 6% would provide coolant for the control rods and thermal shield inner surface; the remainder shall provide fuel element cooling. Exit shall be through the top blowdown nozzles. Turning vanes shall be provided to direct the coolant to the top nozzles. A recess at the top of the simulator vessel is available for a support ring for turning vanes.

An adjustable split ring seal unit, or other means, shall be provided to allow varying the amount of flow between the thermal shield and vessel wall.

4.3 Core Materials and Construction

Core materials shall be 300 series stainless steel, annealed for uniform mechanical properties. The specific stainless steel used shall be one which will not rust under the service conditions. The core assembly shall be of bolted construction, where practicable, to allow testing of various combinations of the core and for access to instrumentation devices for maintenance. Diameter of the vessel shall be checked for roundness prior to core fabrication to insure that the core and seals will fit properly.

4.4 Core Strength and Supports

The maximum allowable load per core support lug is 12,250 lbs. The core, including seal units, shall be designed to withstand the differential pressure producing this load (98,000 lbs. total) in either direction. During blowdown studies, rupture size, pressures,

temperatures and other variables will be regulated so as not to exceed this loading.

The core shall be attached to the core support lugs by bolts, with nuts arranged for access from the top of the vessel. Bolts or nuts shall not be welded to the core support lugs.

4.5 Level Probe Cutout

A cutout of a least 4" diameter shall be provided in the center of the core for the level measuring probe to be used. (See attached sketches.) Means shall be provided to seal around the probe where it penetrates the core to minimize flow bypassing.

4.6 Spray Header

An appropriately sized core spray header and associated spray nozzles shall be installed above the core. The system will simulate an emergency core cooling system. Actual flow shall not be provided.

4.7 Core Component Supports

Size and arrangement of supports for fuel elements and control rods shall be such that the total axial force on the component can be measured with strain gauges at a single location.

4.8 Fuel Rods

Individual fuel rods shall be solid metal.

5.0 Instrumentation

5.1 Description of Existing Facilities

The basic indicating and recording instrument for the CSE experiments consists of two multiplexers, a high and a low speed. The low speed is capable of sampling 2000 points per second. The multiplexer is randomly selectable, 4 points at a time (128 groups of 4 points) and requires a minimum of 3 millivolts DC input at the multiplexer for 1%

accuracy; input is a floating differential. The optimum input range is 10-30 millivolts DC. Each multiplexer point has its own input board with space on each board for scaling resistors and completion bridge. The multiplexer is controlled by a computer, and the sampled data goes into a computer where it is converted from analog to digital values for storage on magnetic tape. Subsequent readout can be by typewriter, paper tape or oscilloscope. A limited amount of selected data can be read out at the time it is taken.

The high speed multiplexer is capable of scanning 24 points at a rate of 10,000 readings per second, each.

5.2 Required Supplemental Instrumentation

Instrumentation compatible with the existing multiplexer and additional instrumentation as required shall be provided to measure and record the variables listed in items 5.2.1 through 5.2.5. All devices to be located inside the vessel shall be capable of functioning as required while withstanding 2500 psig and 600 F. Transducers and strain gauges shall be temperature compensated. Transducers shall be strain gauge type or variable reluctance type. Transmitters, signal conditioning devices and circuitry shall be provided as required to make input signals compatible with the input level requirements of the multiplexer. Where possible, primary devices shall be selected which provide a 0-20 millivolt DC or greater signal.

To the extent practicable, instrumentation installed with the Phase I dummy hydraulic core (see BNWL-CC-703) shall be re-used for the Phase II core.

5.2.1 Long Term Differential Pressure

The design shall provide for two separate systems to measure

long term differential pressure across the core. While only one system will be used, as determined by comparison of similar systems on the Phase I dummy core, both systems shall be shown and described. One system shall use differential pressure transducers mounted inside the vessel. The second system shall use differential pressure transducers mounted outside the vessel. Sensing lines shall be as short as practicable and shall be not smaller than 1/4" I.D.

Transducers for this service shall provide an accuracy of $\pm 2.0\%$ in the range of a 100 psi differential. Provisions shall be made for decreasing the range to 0-50 psi differential while maintaining the $\pm 2\%$ accuracy. Transducers for this service shall be so constructed that no damage is sustained from overranging caused by the rarefaction wave pressure. (1500 psia for 2 milliseconds)

The sensing points for differential pressure transducers shall be located to avoid disturbances from flow entry and exit paths or other areas of high turbulence.

Output of these transducers shall feed to the low speed multiplexer.

5.2.2 Rarefaction Wave Pressure

Pressure transducers shall be provided in three nozzles along the vessel length as specified by the user to measure rarefaction wave pressure. The purpose of these measurements is to enable determining the intensity, velocity, and possible

change of velocity of the wave. Transducers shall be flush with the vessel wall to avoid disturbances arising from the nozzle cavity. Transducers shall have a minimum frequency response of 5000 cps and an accuracy of at least $\pm 5.0\%$ in the range of 0-2500 psi. Provision shall be made for reducing the range to 0-500 psi while maintaining an accuracy of $\pm 5\%$.

Output of the transducers for rarefaction wave pressure measurements shall be fed to the high speed multiplexer.

5.2.3 Static Pressure

The three transducers used for rarefaction wave pressures shall be used for vessel static pressure measurements.

5.2.4 Temperature

Planned instrumentation provides two thermocouples for fluid temperature measurement, one at the top and one at the bottom of the vessel. Additional thermocouples shall be provided to measure fluid temperature at the following locations: core inlet, core outlet, center of three fuel elements, at each side of the bottom core plate, at each side of the rod support plate, at each side of flow baffles, inside the core area but outside the fuel elements, between the core area and the thermal shield, at each outlet nozzle, between the thermal shield and vessel wall. Two spare thermocouples shall be provided at each thermocouple location.

Response time of the thermocouples to a step temperature change shall be a maximum of 10 milliseconds to the 63% point of the ultimate value. Output of the thermocouples shall be fed to the low speed multiplexer

5.2.5 Forces on Core Components and Supports

Direct measurement of forces on core support lugs shall be provided by strain gauges or load cells located inside or otherwise attached to the eight bolts supporting the core assembly.

Output of these devices shall be fed to the high speed multiplexer. Frequency response of these devices shall be 5000 cps minimum. Accuracy shall be $\pm 5\%$ in the range required for pressure drops across the core of 0-1500 psi. Provisions shall be made for reducing the range of each device by a factor of three while maintaining an accuracy of $\pm 5\%$.

The core component forces shown in Tables I and II following shall also be measured by use of strain gauges or other suitable force measuring devices:

5.2.5 Forces on Core Components and Supports

Direct measurement of forces on core support lugs shall be provided by strain gauges or load cells located inside or otherwise attached to the eight bolts supporting the core assembly.

Output of these devices shall be fed to the high speed multiplexer. Frequency response of these devices shall be 5000 cps minimum. Accuracy shall be $\pm 5\%$ in the range required for pressure drops across the core of 0-1500 psi. Provisions shall be made for reducing the range of each device by a factor of three while maintaining an accuracy of $\pm 5\%$.

The core component forces shown in Tables I and II following shall also be measured by use of strain gauges or other suitable force measuring devices:

TABLE I PRIMARY FORCE INSTRUMENTATION

Core Component	No. of Core Components to be Instrumented	No. of Devices per Component and Location	Readout	Remarks
Core Support Bolts	8 core support bolts	1 inside or otherwise attached to bolts	High speed Multiplexer	To measure tensile and compressive forces
Fuel Element	2	1 (plus 1 spare) on fuel element support	High speed Multiplexer	To measure tensile and compressive forces on a fuel element
Control Rods	2	1 (plus 1 spare) on control rod support	High speed Multiplexer	To measure tensile and compressive forces on a control rod
Core Spray Header	Each header support and header pipe	1 per support 1 on header midway between supports	High speed Multiplexer	Measure forces on spray header and bending of header.

TABLE II SECONDARY FORCE INSTRUMENTATION

Core Component	No. of Core Components to be Instrumented	No. of Devices per Component and Location	Readout	Remarks
Fuel Rod	3 in different elements	2 @ 90° on plan midway between spacers and 2 @ 90° on plan at bottom	High speed Multiplexer	To measure tensile and compressive forces and period plus bending from vibration, if any.
Fuel Element Shroud	2	4 two at bottom and two at center on adjacent sides	High speed Multiplexer	To measure period and bending from vibration, if any.
Control Rods	2	2 @ 90° on plan at center and 2 @ 90° on plan at bottom	High speed Multiplexer	To measure period plus bending from vibration, if any.
Thermal Shield	1	4 (1 ft. from bottom opposite each other, 2 @ 90° to each other, each location.	Low speed Multiplexer	To measure longitudinal stress and circumferential stress in thermal shield.
Top and Bottom Core Plates	Top and bottom core plate	1 each, one foot from plate outer radius	Low speed Multiplexer	To measure bending and radial and tangential forces. (Rosette arrangement)

Location of devices shall be selected to provide sufficient strain to produce signals compatible with the multiplexer input requirements.

5.3 Instrumentation Leads

Instrumentation leads located inside the vessel shall be protected from the high temperature, high pressure environment and shall be mechanically protected from the forces occurring during blowdown. Insofar as practicable, leads shall be grouped or arranged so that the core with attached devices and leads may be installed as a unit with a minimum of separate lead runs.

Means shall be provided for sealing the leads where they penetrate the vessel at the instrument ring or nozzles. Instrument lead wires shall be terminated at a junction box in the 277-T Building at a distance of about 10 feet from the vessel.

5 506
 10 11 7 0 0 2 3 7 66

DET. "1"

THERMAL SHIELD

MAT 300 SERIES SST

MIG C
 CONT. C ROD
 SUPPORT R

FUEL ELEMENT LENGTH = 95"

REACTOR CORE
 CONT. C ROD
 SUPPORT R
 DWG
 NO
 SECT 101 FUEL C 500

REACTOR
 TYP. SECT

Section "A-A"

Note: Preliminary design of probe shown for information & cross-sectional dimensions.

SIMULATOR VESSEL LEVEL PROBE

SYMBOLS

- ◇ THERMOCOUPLE LOCATIONS
 - PRESSURE TRANSDUCER FOR RAREFACTION WAVE PRESSURES & STATIC PRESSURE
 - ◇ STRAIN BOLTS (AS SHOWN)
 - ◇ DIFFERENTIAL PRESSURE TRANSDUCER (INTERNALLY MOUNTED)
 - ◇ DIFFERENTIAL PRESSURE TRANSDUCER (EXTERNALLY MOUNTED)
 - STRAIN GAGE LOCATION
- (SEE TABLE I & II FOR ADDITIONAL DESCRIPTION OF LOCATIONS AND FOR ADDITIONAL LOCATIONS)

CONTAINMENT SYSTEMS EXPERIMENT
PHASE I DUMMY HYDRAULIC CORE
ASSEMBLY INSTRUMENTATION
LOCATION SKETCH
BUREAU OF NUCLEAR ENERGY
RESEARCH