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**INSTRUMENTATION DEVELOPMENT
FOR THE CONTAINMENT SYSTEMS EXPERIMENT**

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PACIFIC NORTHWEST LABORATORY operated by BATTELLE MEMORIAL INSTITUTE

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INSTRUMENTATION DEVELOPMENT
FOR THE CONTAINMENT SYSTEMS EXPERIMENT

By

C. E. Huck

Chemical Laboratory
Chemical Department

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BATTELLE-NORTHWEST
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INTRODUCTION

This report describes the instrument development program and the detailed instrumentation requirements for the Containment Systems Experiment (CSE). The CSE will include a number of test runs in which several nuclear reactor containment concepts will be evaluated during simulated reactor coolant line ruptures⁽¹⁾. The results will be of use to reactor designers in more accurately and economically specifying materials and components for future nuclear reactor containment systems. Many of the transducers and signal transmission systems must operate under unfavorable environmental conditions, as indicated by the following anticipated ambient conditions:

Inside the reactor simulator vessel: 600F and 2500 psig, steam and demineralized water.

In the dry-well : 300F and 150 psig, steam and water

In the wet-well : 200F and 25 psig, steam and water

In the containment vessel : 270F and 70 psig, steam and water

Development, testing, and adaptation of components will be required. A large number of variables such as temperature, pressure, stress, liquid level, humidity, discharge rate, and impact must be measured during the dynamic runs in order to achieve the experimental objectives. PC&EDO will develop and specify the transducers and signal transmission systems for reading into the peripheral equipment of a digital computer⁽²⁾. The computer and the peripheral equipment are to be specified and developed by Physics and Instruments Laboratory (PIL) with programming to be done by PC&EDO. PC&EDO will closely coordinate its activities with the work to be done by PIL and by Chemical Effluents Technology (CET).

PROGRAM

The PC&EDO program has two objectives:

- I. Selection and specification of the transducers and signal transmission systems.
- II. Programming of the on-line digital computer to process the experimental information.

In support of the first objective, an integrated, three-phase development and testing program has been initiated.

The first phase will consist of laboratory tests of components in laboratory furnaces or other locations where CSE environmental conditions may be simulated. Phase 1 will also include tests of various types of strain gages, their mounting methods, waterproofing methods, and methods of temperature compensation.

Phase 2 will include tests of selected components during scaled-down CSE blowdown tests in tanks located in 300 area cold laboratories or in plant areas. One such tank with a pressure rating of 200 psig was recently obtained from offsite. This tank will be moved from its present location at the 271 CR bldg., 200 East Area, to the Tank Farm outside 321 building. There the tank will be used in some of the scaled-down CSE tests and for instrument development purposes. Present plans are for PC&EDO development using the 200 psig tank to begin about March 1, 1965, and to terminate about September 1, 1965. During phase 2, samples of the transducers, the transducer connectors, the connecting cables, cable end seals, and any required transducer protective housings or water cooling jackets will be operationally and environmentally tested.

Phase 3 will consist of installing and calibrating all components in the 221-T bldg. CSE facility preparatory to the start of blowdown runs.

All three phases may overlap in time but the goal is to complete phase 1 by August 1, 1965; to complete phase 2 by November 1, 1965; and to have selected 75% of the components and placed orders for them by the end of phase 1. In this manner all components should be specified well ahead of the expected reactor simulator vessel delivery date of December 1, 1965 and be available for installation and beneficial use on the 271-T CSE facility by January 1, 1966, the expected start-up date for blowdown tests.

A conductivity probe incremental water level monitor for the reactor simulator vessel will require development. Some development has already been done on the gamma radiographic total water monitor for the reactor simulator vessel using a 1/2 curie Cs137 source, a scintillator, and a count rate meter. This method appears to be feasible but several materials and environmental problems remain to be solved before the radiographic method may be used in the 2500 psig, 600 F environment of the simulator vessel.

In particular, an efficient gamma photon detector resistant to the environmental conditions is not currently available. This detector must be rugged enough to be sealed into the reactor simulator vessel wall. Water-cooling will partially alleviate the temperature problem but selection of a pressure resistant detector remains a problem.

A humidity monitoring system has been obtained for evaluation. No development is foreseen for the humidity monitor except possibly for protection of the lithium chloride sensors.

An air current velocity monitor is also required with sensors at 15 different locations. No development is foreseen for this instrument except as required for protection of the sensors. A special calibration of the system appears necessary to accurately monitor mixtures of air, steam, and entrained water vapor.

The digital computer programming task can be divided into three major program areas:

1. Data logging; this program causes:
 - a. the high speed multiplexer to be connected to sets of 4 analog voltages in a prescribed sequence,
 - b. the analog-to-digital converter to successively convert the voltages, and
 - c. the resulting digital representation to be written on magnetic tape.
2. Data reduction and conversion; this program processes the data accumulated on magnetic tape, converts it into engineering units, computes statistical data, and types and punches out the results.
3. Multichannel analyzer; a program is required to make the digital computer function as a multichannel analyzer.

All computer programming should be completed by January 1, 1966. The initial effort should be concentrated on area 1, then 3, and then 2, in that order. Since small digital computers have been used as multichannel analyzers in previous applications, the third area of programming should consist only of modifying existing programs to suit our needs. Area 2 also might be quite simple. If a decision is made to do the data processing on a large scale digital computer this area would then simply be the conversion of the magnetic tape data to another format.

MEASUREMENT REQUIREMENTS

The following measurement needs are currently foreseen:

A. Temperatures

A total of 87 thermocouples (T/C's) and resistance temperature detectors (RTD's) will be applied at various locations within the CSE system. Some of the T/C response times (to the 63% point) must be 0.1 sec or faster to read out reactor simulator temperatures satisfactorily during the 8 in nozzle blowdown runs. A T/C with as high an output as possible will be selected to overcome an expected input multiplexer noise level of several hundred microvolts. Chromel-Constantan with an output of about 20 mv for the 0 to 600 F temperature range appears to be a good compromise between signal level and cost. Of the 87 T/C's and RTD's, no more than 70 will be used at one time. Of these 70, 50 are used to give the average temperature of the containment vessel.

1. Reactor simulator vessel T/C locations

- 1.1 Two inside the vessel; one will measure air temperature in the top airspace before and after blowdown; the other will measure water temperature at the bottom before and after blowdown.
- 1.2 Sixteen at locations designated TC₁, TC₂, TC₃, TC₇, and TC₈ on drawing SK-2-3580. These T/C's will measure temperatures at the outside, half depth, and near depth of the vessel shell before and after blowdown.

2. Dry well T/C locations

- 2.1 One in the airspace between nozzles D and E to measure air temperature before and after blowdown.
- 2.2 Two; one on each side of the dry well shell at the same elevation as the top of the wet well. These T/C's will measure the temperature differential across the steel shell.
- 2.3 Two; one on each side of the dry well shell at the elevation of nozzle 20. These T/C's will measure the temperature differential across the steel shell.

3. Wet well T/C locations

- 3.1 Two T/C's; one in the airspace, and one in the water space below the no. 36 access hole for measuring the ambient temperatures at these locations.

4. Containment Vessel T/C and RTD locations

- 4.1 Ten T/C's, equally distributed throughout the volume, for high speed measurements of selected temperatures in the containment vessel. These data are required for leakage calculations. These T/C's will be placed and removed at will.
- 4.2 Forty precision RTD's, equally distributed throughout the volume, for measuring the average temperature in the containment vessel to a precision of ± 0.1 F and with a 63% response time of 20 seconds or faster in air at 60 fpm.
- 4.3 Six T/C's; one on each side of the shell at three equidistant elevations. These T/C's will measure the temperature differential across the shell.

- 4.4 One 0.025 inch diameter nickel resistance wire about 600 to 700 ft long for measuring the average temperature change in the outer containment vessel during leakage rate tests. This wire will be installed so as to expose equal increments of wire length to equal increments of volume within the outer containment vessel.

5. CSE Cell and Canyon RTD Locations

- 5.1 Six RTD's, three equally spaced vertically on opposite sides of the outer containment vessel, for measuring selected air temperatures in the cell and canyon. These precision RTD's will be identical to those listed in paragraph A, 4.2 above. The RTD's may be relocated at will and additional RTD's may be added in groups of four by inserting additional input modules in the input multiplexer.

B. Pressures

A total of 19 absolute and differential pressure transducers will be required throughout the system, based on the experimental objectives and on previous containment system tests at the G. E. Company Atomic Power Equipment Department⁽³⁾ and at the Babcock and Wilcox Co.⁽⁴⁾. The first transient pressure pulse occurred at about 0.25 sec and 0.5 msec, respectively, after rupture of the diaphragm for the two series of tests mentioned in references (3) and (4). In order to measure the faster of the two pressure pulses the minimum transducer frequency response must be 2,000 CPS. Strain gage pressure transducers will be used to provide this frequency response while also providing adequate resolution, linearity, precision, and accuracy. In addition, strain gage transducers generally maintain their dynamic calibration when calibrated statically. As an aid in measuring dynamic liquid level in the reactor simulator vessel and in the wet well three of the 19 pressure transducers should be differential pressure transducers.

1. Reactor simulator vessel pressure transducer locations

- 1.1 Two absolute pressure transducers, one in the top air space and the other in the bottom of the reactor simulator.
- 1.2 One differential pressure transducer connected between taps in the top and bottom of the reactor simulator for use in monitoring dynamic liquid level.
- 1.3 Four absolute pressure transducers, three will be closely spaced in the orifice reducing flange and one will be in the nozzle step fitting. Transducers will be relocated to the particular nozzle used for each test.

2. Dry well pressure transducer locations

- 2.1 Three absolute pressure transducers in the dry well; one mounted at the top, near nozzle E; one mounted at the bottom, near nozzle D; and one mounted inside and near the entrance of one of the dry well vent pipes.

3. Wet well pressure transducer locations

- 3.1 Two absolute pressure transducers, one in the air space below the No. 36 access hole and one in the liquid at the vent pipe exit, directly below the No. 36 access hole.
- 3.2 Two differential pressure transducers, one connected between the No. 30 and the No. 32 nozzle headers for specific gravity readout and the other connected between the No. 30 nozzle header and the No. 9 upper vent for weight factor readout. These two transducers will provide accurate liquid level readings for the wet well.

4. Containment vessel pressure transducer locations

- 4.1 Five absolute pressure transducers, one located directly above the pressure transducers in the dry well (above nozzles D and E), and the other four located at selected points inside the outer containment vessel.

C. Stresses and Strains

A total of 160 active strain gages will be located on various structural members, and on each of the concentric containment vessels. Specific, known locations are on each of the vessel legs and bracing struts, on the simulated reactor core assembly, inside the flange bolts which hold the impact or deflector plate in place, and near the welds at the intersections of the wet well baffles with the outer shell of the dry well and with the shell of the outer containment vessel.

- 1.1 Twelve strain gages, one located on each of the simulator vessel legs and bracing struts.
- 1.2 Four strain gages located inside the four flange bolts supporting an impact plate.
- 1.3 40 strain gages attached to the primary vessel; two each for measuring hoop and longitudinal stresses in the cylinder, meridional and hoop stresses in the top and bottom heads, stress concentrations at the nozzles, and stress concentrations at the vessel support areas.

- 1.4 20 strain gages for measuring the stresses in a simulated reactor core assembly.
- 1.5 40 strain gages, some located near the welds at the intersection of the wet well baffles and the dry well outer shell, and some located near the welds at the intersection of the wet well baffles and the outer containment vessel. Other possible stress concentration areas such as those near the 24 in vent pipe welds will also be monitored with strain gages.
- 1.6 44 strain gages located at selected locations on the outer containment vessel walls. These strain gages will be mounted at locations where stress concentrations are expected and at other locations to obtain a representative map of stresses in the vessel shell.

D. Weights and Forces

- 1.0 14 strain gage load cells, one located on each of the vessel legs and supporting struts, for measuring forces to hold the primary vessel in place during a blowdown and for use in dynamic liquid level measurements.

E. Impact of Jet

- 1.0 One impact probe on the jet impact plate. The transducer will probably be piezoelectric type but may also be a strain gage type accelerometer.

F. Dynamic Total Water Monitor in the Simulator

- 1.0 Three gamma radiographic systems used to monitor the total water content of the reactor simulator vessel. This system is under development. The signal output is a train of scintillation pulses of up to 10^6 CPS which will be monitored by the computer approximately every 0.1 second. The signals from all three scintillators will be combined to indicate total water content in the simulator.
- 2.0 41 go - no go signals from conductivity probes equally spaced vertically inside the vessel at 5-inch intervals. The success of this method depends on the existence of a significant conductivity difference between water and steam at 600F and 2500 psig. A suitable high integrity pressure seal and the maintenance of some minimum value of insulation resistance are also required. An incremental ultrasonic probe system might be substituted for the conductivity system if development so indicates.

G. Humidity

A total of 6 humidity probes will be required in the CSE system, some of which will be fixed and some portable. None of the probe signals will be processed by the computer but, instead, will be read out by means of a small indicator in the control room. All relative humidity (RH) readings will be made before blowdown, and after blowdown and cooling. Lithium chloride sensors will be used which are accurate to $\pm 2\%$ of full scale. Full scale range will be from 41% to 99% at 80 F. Dry bulb temperature at each location will be sensed by a thermistor. The humidity factor and the dry bulb temperature will be used to determine relative humidity.

1. Wet Well humidity probe locations

- 1.1 One, provided for by mounting a bulkhead connector in the wet well. The portable cable-mounted probe will be manually connected each time humidity is measured in the wet well.

2. Dry Well humidity probe locations

- 2.1 One, provided for by mounting a bulkhead connector in the dry well. The portable cable-mounted probe will be manually connected each time humidity is measured in the dry well.

3. Containment vessel humidity probe locations

- 3.1 Four in the outer containment vessel, equally distributed vertically.

H. Air Currents

Fifteen sensors above the floor level (elevation = 5'6") in the containment vessel. These sensors will probably be heated thermopile type sensitive to flow velocity. The sensors will be equally spaced along horizontal supporting members located throughout the containment vessel air space. These air current monitors will be used in initial outer containment vessel leakage rate tests and in later CSE blowdown tests.

Plans are to obtain a two probe, velocity-sensitive electronic air flowmeter for evaluation to determine its adaptability to measuring steam and air flow rates at 50 psig and at various steam qualities and/or superheats.

ESTIMATED INSTRUMENT COMPONENT COSTS

<u>Quantity</u>	<u>Component</u>	<u>Price Each Or Per Channel</u>	<u>Total Cost</u>
41	Chromel-Constantan T/C's bare wire tips with mineral insulation and end seals. Length = 30 ft.	\$2/ft	\$ 2 460.00
46	Platinum RTD's, certified repeatable to .01%, accurate to 0.1°F, including 100 ft leads, bridge circuitry, and power supplies.	\$174.37	8 021.00
1	700 ft length of .025 india RTD grade Ni wire	\$3.30/ft	2 310.00
19	Absolute and differential strain gage pressure transducers	\$350.00	6 650.00
160 pairs	Strain gages, weldable with 30 ft integral leads, and ceramic-insulated. (Each pair includes a dummy gage required for temperature compensation.)	\$100.00	16 000.00
14	Load cells, strain gage type with temperature compensation and usable in tension and compression	\$400.00	5 600.00
1	One impact probe, piezoelectric or strain gage	\$350.00	350.00
3	Gamma radiographic systems, each consisting of a scintillation crystal, PM tube, preamplifier, amplifier-discriminator	\$605.00	1 815.00
2	Cs ¹³⁷ 1/2 curie gamma sources	\$350.00	700.00
41	Conductivity probe systems, each consisting of 30 ft. of mineral-insulated cable, a high pressure seal, and an indicator unit.	\$00.50/ft	615.00
1	Humidity system consisting of 7 probes and one indicator. One probe will be for use as a spare.	\$1 195.00	1 195.00
1	Air current monitor consisting of 15 sensors and one indicator	\$2 400.00	2 400.00
Subtotal			48 116.00
20% Contingency			9 623.00
Total Cost			<u>\$57 739.00</u>

Estimated Costs of Electronic Equipment, Prototype Transducers and Strain Gages

In addition to the commercially available transducers and wiring equipment listed above, a need is anticipated for a considerable number of strain gage elements and transducers for test and evaluation purposes. Some electronic equipment is also needed for developmental use and for possible later use during CSE experimental runs. The electronic equipment costs may be estimated fairly accurately at this time, but an accurate cost figure for the components to be tested is not possible. The contingency of 20% used in estimating the instrument component costs should be enough to include all components obtained for evaluation. Costs of electronic equipment for which a known need exists are estimated below.

<u>Quantity</u>		<u>Cost</u>
1	Two channel memory oscilloscope including amplifiers and time base units	\$ 2 200.00
1	Portable two-channel wide deflection oscillographic recorder	4 000.00
1	Fast balancing RLC impedance bridge	500.00
2	Low range strain gage pressure transducers for dynamic water level measurement during radiographic water level monitor development	850.00
1	Laboratory oven 0 - 600F, with blower	725.00
1	100 mc Events-per-unit time meter	3 000.00
1	Strain gage null balance readout meter and switching unit	980.00
1	Thermocouple compensator, 48 point	<u>1 180.00</u>
	Subtotal	13 435.00
	10% Contingency	<u>1 344.00</u>
	Total	<u>\$14 779.00</u>

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4. Luken, R. C., and Leeman, C. A.; Vapor Suppression Test Program Report, BAW-1258, Aug. 1962, Uncl.

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