Enclosure to
BG&E letter to NRC
Dated April 10, 1984

Baltimore Gas and Electric Company
Calvert Cliffs Nuclear Power Plant
Units 1 and 2
Reactor Vessel Level Monitoring System
Licensing Report

April 1984

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ATTACHMENT

(1) NRC Generic Letter 82-28 Checklist

REFERENCES

1.0 INTRODUCTION

1.1 Purpose

In response to NRC Generic Letter 82-28, this report describes the design of the Reactor Vessel Level Monitoring System to be installed in the Calvert Cliffs Nuclear Power Plant Units 1 and 2 pursuant to NUREG-0737, Item II.F.2.

1.2 Summary of Activities

As discussed in Reference (B), Baltimore Gas & Electric Company (BG & E) has participated in the Combustion Engineering Owner's Group (CEOG) program for evaluation of instrumentation to detect inadequate core cooling in acordance with NUREG-0737, Item II.F.2. An outline of the CEOG evaluation of response characteristics of instrumentation under conditions of Inadequate Core Cooling (ICC) was initially discussed with the NRC staff at a meeting in Bethesda, Maryland, on May 28, 1980. The CEOG program for evaluation of ICC instrumentation is described in References (C) and (D).

In Reference (A), the NRC stated that the generic C-E HJTCS is "...acceptable for tracking reactor coolant system inventory and provide(s) an enhanced ICC instrumentation package when used in conjunction with core exit thermocouple systems and subcooling margin monitors designed in accordance with NUREG-0737 and operated within approved emergency operating procedure guidelines." In Reference (E), BG & E stated its intentions of installing the Combustion Engineering, Inc. (C-E) Heated Junction Thermocouple System (HJTCS) as the reactor vessel inventory measurement system for the Calvert Cliffs plant. Reference (F) provided the installation schedule for this system. The HJTCS is designed to meet the Reactor Vessel Level Monitoring System (RVLMS) guidance for ICC Instrumentation in accordance with NUREG-0737, Item II.F.2, and NRC Regulatory Guide 1.97, Revision 3. The details of the initial design activity for the C-E HJTCS were discussed with the NRC staff at a meeting in Bethesda, Maryland on March 4, 1981.

1.3 Basis for RVLMS Instrument Selection

The result of initial studies by the CEOG associated with ICC instrumentation are documented in Reference (G). These studies have been based on the objective to indicate the aproach to, the existence of, and the recovery from ICC. Following an evaluation of several possible sensor systems for a complete ICC detection system, the studies determined that a three element system would meet the objectives for ICC detection:

(1) Subcooled Margin Monitor;
(2) Heated Junction Thermocouple System; and
(3) Core Exit Thermocouple System.

This report concerns the heated junction thermocouple sub-system of the planned ICC detection system for the Calvert Cliffs plant.

The RVLMS/HJTCS portion of the ICC detection system displays, trends, and logs the HJTC sensor outputs to enable the operator to monitor reactor vessel level (inventory) during conditions associated with the approach to and the recovery from ICC.

2.0 SYSTEM FUNCTIONAL DESCRIPTION

2.1 Reactor Vessel Coolant Inventory Measurement Functional Objectives

During an ICC event caused by loss of coolant inventory (e.g., small break loss of coolant accident), the reactor coolant system (RCS) remains subcooled until enough coolant is lost to reduce primary system pressure to that corresponding to saturation temperature. The RCS remains at saturation conditions until sufficient coolant is lost to lower the two-phase level to the top of the active core. The function of the RVLMS is to provide a direct reactor vessel inventory measurement during the approach to ICC when the two-phase coolant level in the reactor vessel is decreasing, and during subsequent recovery. The parameter which is measured is the collapsed liquid level above the fuel alignment plate. The collapsed level represents the amount of liquid mass which is in the reactor vessel above the core. Measurement of the collapsed water level was selected in preference to measuring two-phase level, because it is a direct indication of the water inventory while the two-phase level is determined by water inventory and void fraction.

The level range extends from the top of the vessel down to the top of the fuel alignment plate. The response time is short enough to track the level during small break loss of coolant accident (LOCA) events. The resolution is sufficient to show the initial level drop, the key locations near the hot leg elevation and the lowest levels just above the alignment plate. This provides the operator with adequate reactor vessel level indication to track the progression of an ICC event due to coolant inventory loss during approach to and recovery from the event and to monitor the consequences of his mitigating actions or the ability of automatic equipment to function.

2.2 Functional Performance During Accident Conditions

Reference (I) discussed the response of the HJTCS to loss of inventory accidents (e.g., LOCA) with and without reactor coolant pumps running. The performance characteristics of the HJTCS during a variety of reactor transient scenarios (i.e., small break LOCAs, steam line breaks, and steam generator tube ruptures) were evaluated on a best estimate basis. The results of this investigation showed that the HJTCS can provide significant information about the status of the liquid inventory above the fuel alignment plate when the reactor coolant pumps are not in operation. Furthermore, although the collapsed liquid level display is biased when the reactor coolant pumps are operating during a transient, the HJTCS still provide important information on the trend of liquid inventory in the reactor vessel. As such, the HJTCS fulfills the NRC Regulatory 1.97, Revision 3, guidelines to detect the trend of voids in the reactor coolant system with the reactor coolant pumps running.

While References (D) and (I) provide a more detailed explanation of the consequences of the loss of a HJTC sensor assembly, it can be said in summary that such a failure would have minimal effect on the ability to detect an approach to ICC (in the interval where the HJTCS is required to operate) since:

- The HJTCS includes two identical channels of instrumentation;

- For each HJTC probe assembly, at least two HJTC sensor assemblies indicate upper head level, which would indicate the first vessel inventory decrease;

- The HJTC sensors are spaced close enough (especially in the three areas of importance: upper head; hot leg nozzle; and immediately above the fuel alignment plate) that failure of one sensor would have minimal effect on inventory tracking resolution;

- The operator has other instrumentation at his disposal to detect the approach to ICC.

It has been concluded that the HJTCS can provide meaningful information to the operator from the onset of reactor vessel inventory loss during the approach to and recovery from ICC. The HJTCS also provides an effective indication of the results of corrective actions taken by the reactor operator.

3.0 SYSTEM DESIGN DESCRIPTION

THE C-E HJTCS has been selected as the basic RVLMS instrumentation system to meet the functional objectives described in Section 2. The Calvert Cliffs plant specific design of the HJTCS is described in this section, which addresses (1) sensor design; (2) cabling; and (3) signal processing, display, and alarms.

Firgure 3-1 is a functional diagram for the HJTCS. The system consists of two safety grade channels from sensors through signal processing equipment. The outputs of the processing equipment feed channelized safety grade displays and trend recorders in the control room and displays on the signal processing cabinets. In addition, outputs are provided for use in the plant's safety parameter display system (SPDS) currently under development. The SPDS will provide the primary display for the HJTCS.

3.1 Sensor Design

The HJTC system measures reactor coolant liquid inventory with discrete HJTC sensors located at different levels within a separator tube ranging from the fuel alignment plate to the reactor vessel head. The basic principle of system operation is detection of a temperature difference between adjacent heated and unheated thermocouples.

As pictured in Figure 3-2, the HJTC sensor consists of a Chromel-Alumel thermocouple near a heator (or heated junction) and another Chromel-Alumel thermocouple positioned away from the heater (or unheated junction). In a fluid with relatively good heat transfer properties, such as water, the temperature difference between the adjacent thermocouples is very small. In a fluid with reltively poor heat transfer properites, such as steam, the temperature difference between the thermocouples is large.

Two design features ensure proper operation under all thermal-hydraulic conditions. First, each HJTC is shielded to avoid overcooling due to direct water contact during two phase fluid conditions. The HJTC with the splash shield is referred to as the HJTC sensor (See Figure 3-2). Second, a string of HJTC sensors is enclosed in a tube tha separates the liquid and gas phases that surround it.

The Calvert Cliffs HJTC probe asemblies are of the "Full Length Probe" design, housed within a separator tube inside a CEA shroud. Of the eight HJTC sensor assemblies in each probe assembly, two are located above the CEA shroud,in the upper area of the reactor vessel closure head, and one more is located near the top of the CEA shroud. Three other HJTC sensors are located near the top, centerline and bottom of the hot leg nozzle elevations, respectively. A seventh sensor is located approximately equidistant between the bottom hot leg area sensor and the lowest sensor, which is located less than one foot from the top of the fuel alignment plate.

The separator tube creates a collapsed liquid level tht the HJTC sensors measure. This collapsed liquid level is directly related to the average liquid fraction of the fluid in the

reactor head volume above the fuel alignment plate. This mode of direct in-vessel sensing reduces spurious effects due to pressure, fluid properties, and non-homogeneities of the fluid medium. The string of HJTC sensors and the separator tube is referred to as the HJTC instrument.

The HJTC System is composed of two channels of HJTC instruments. Each HJTC instrument is manufactured into a probe assembly. The probe assembly includes eight (8) HJTC sensors, a seal plug, and electrical connectors (Figure 3-3). The eight (8) HJTC sensors are electrically independent and are each located at different levels from the reactor vessel head to the fuel alignment plate.

Each HJTC probe assembly is housed within a support tube assembly installed within the reactor vessel. Figure 3-4 describes the representative locations of the two support tube/probe assemblies. The support tube assemblies, shown in Figure 3-5, are installed within vacated Part Length Control Element Drive Mechanism (PLCEDM) shrouds in the upper guide structure. The upper pressure boundary of the applicable PLCEDM nozzle is modified to facilitate the HJTC probe assembly penetration through the reactor vessel.

3.2 Cabling

The cabling and connections for the HJTCS are channelized, Class 1E safety grade cabling from the HJTC signal processing cabinets, and to the safety grade displays and trend recorders. The cabling frm the sensors to the signal processing cabinet pass not only the individual HJTC signals, but also the HJTC heater power.

The two seperate HJTCS channels are powered from separate reliable Class 1E power sources.

3.3 Signal Processing, Display and Alarm Equipment Design

3.3.1 Display

The SPDS will provide the primary HJTCS display. The backup display will consist of a seismically qualified Class 1E light array located in the control room. Lights corresponding to each discrete HJTCS sensor location are driven via contact outputs of the HJTCS cabinets. The lights continuously indicate HTJC sensor being covered or uncovered, as determined by the HJTC processing equipment.

An additional display is also provided on each HJTC signal processing cabinet, to be used for detailed information and system diagnostics. The following information can be presented on the HJTC digital display on the processing cabinet:

(1) Percent liquid inventory level above the fuel alignment plate derived from the eight discrete HJTC positions.

(2) Unheated junction temperature at eight positions.

(3) Heated junction temperature at eight positions.

(4) Temperature difference between heated and unheated junctions at eight positions.

(5) System diagnostic information.

Class 1E trend recorders are also provided in the control room for each HJTCS channel, to provide reactor vessel inventory tracking capability in accordance with NRC Regulatory Guide 1.97, Revision 3. The trend recorders are driven via analog outputs from the HJTCS processing cabinets.

3.3.2 Alarms

Both channels of HJTCS processing cabinets provide contact outputs to the plant annunciator system to alert the operator (1) that the collapsed reactor vessel water level has fallen below the top HJTC sensor; or (2) that there is a malfunction in the RVLMS. Malfunctions of which the operator will be aware include HJTC processor malfunction, HJTCS cabinet power failure, or a questionable HJTC sensor signal.

3.3.3 Signal Processing

The HJTCS signal processing cabinets are located in the switchgear rooms of the auxiliary building.

The processing equipment for the HJTCS performs the following functions:

(1) Determine if liquid inventory exists at the HJTC positions. The heated and unheated thermocouples in the HJTC instrument are connected in such a way that absolute and differential temperature signals are available. This is shown in Figure 3-6. When water surrounds the thermocouples, their temperatures and voltage output are approximately equal. V (A-C) on Figure 3-6 is, therefore, approximately zero. In the absence of liquid, the thermocouple temperatures and output voltages become unequal, causing V (A-C) to rise. When V (A-C) of the individual HJTC rises above a predetermined setpoint, liquid inventory does not exist at this HJTC position.

(2) Determine the maximum upper plenum/head fluid temperature from the top three unheated thermocouples. The temperature processing range is from 100,F to 1800,F.

(3) Process all inputs and calculated outputs for display.

(4) Provide an alarm output contact to the plant annunciator system when an HJTC sensor detects the absence of liquid level.

(5) Provide control of heater power for proper HJTC output signal level. Figure 3-7 shows a single channel design which includes the heater power controller.

(6) Provide an analog output for liquid inventory level above the fuel alignment plate.

4.0 SYSTEM VERIFICATION TESTING

The HJTC system has been specifically developed to indicate liquid inventory above the core. Since it is a new system, extensive testing has been performed to assure that the HJTC system will operate to unambiguously indicate liquid inventory above the core.

The testing was divided into three phases:

Phase 1 - Proof of Principle Testing (Reference (J))
Phase 2 - Design Development Testing (Reference (K))
Phase 3 - Prototype testing (Reference (L))

The first phase consisted of a series of five tests, which have been completed. The testing demonstrated the capability of the HJTC instrument design to measure liquid level in simulated reactor vessel thermal-hydraulic conditions (including accident conditions). The five tests which constituted the Phase 1 proof of principle testing program are:

Test 1	Autoclave test to show HJTC (thermocouples only) response to water or steam.
Test 2	Two phase flow test to show bare HJTC sensivity to voids.
Test 3	Atmospheric air-water test to show the effect of a splash shield.
Test 4	High pressure boil-off test to show HJTC sensor response to reactor thermal-hydraulic conditions.
Test 5	Atmosphere air-water test to show the effect of a separator tube.

The Phase 2 test program consisted of a series of steady state and transient tests under single phase and two phase fluid conditions with an HJTC probe assembly. Fluid conditions that the probe might be exposed to were simulated. The Phase 2 tests verified that the HJTC probe assembly is capable of measuring water inventory in a reactor vessel.

The Phase 3 test progrm consisted of high temperature and pressure testing of the manufactured prototype system HJTC probe assemebly and processing electronics. This test program verified the HJTC prototype performance under simulated accident conditions that could exist in a reactor vessel.

5.0 QUALIFICIATION

5.1 Sensors

The in-vessel sensors meet the NUREG-0737 Appendix B guidelines for qualification. The sensor design is consistent with the NUREG-0737, Item II.F.2 guidelines, including the clarification thereof. Specificially, the HJTC probe assemblies are designed such that they meet the appropriate stress criteria when subjected to normal and design basis accident loadings.

5.2 Cabling

The out-of-vessel portion of the HJTC probe assembly consists of the pressure boundary seal plug and short sections of mineral insulated cables from each sensor, with hermetically sealed attached connector halves. This out-of-vessel portion of the probe assembly is environmentally and seismically qualified to Class 1E criteria in accordance with NUREG-0588 and IEEE Standards 323-1974 and 344-1975 guidance for a harsh environment. The qualification envelopes the design basis accidents for Calvert Cliffs as described in the Calvert Cliffs Units 1 and 2 Updated Final Safety Analysis Report. References (M) and (N) describe the methods used to meet the qualification criteria for the HJTCS.

The in-containment cabling, connections, and containment penetrations for the HJTCS will be seismically and environmentally qualified in accordance with NUREG 0588 and IEEE Standards 323-1974 and 344-1975 guidance, for a harsh environment. The out-of-containment cabling and connections will be qualified to those standards.

5.3 Signal Processing, Displays, and Alarm Equipment

The Class 1E safety related HJTCS cabinets and cabinet displays are qualified in accordance with NUREG-0588 and IEEE Standards 323-1974 and 344-1975 guidance for a mild environment. References (M) and (N) describe the methods used to meet the qualification criteria for the HJTC signal processing cabinets, including the cabinet mounted display.

The operator's light array display in the control room and the trend recorders for the HJTCS will be qualified.

6.0 OPERATING INSTRUCTIONS

Plant specific emergency operating procedures for use of the information from the RVLMS/HJTCS will be developed taking into account recommendations from the C-E Generic Emergency Procedure Guidelines, CEN-152. Revision 2 of this generic document is currently being prepared for the C-E Owners Group and is expected to include Emergency Procedure Guidelines for the RVLMS/HJTCS.

Calvert Cliffs procedures will be modified to include material associated with the use of RVLMS/HJTCS prior to the system being declared operable.

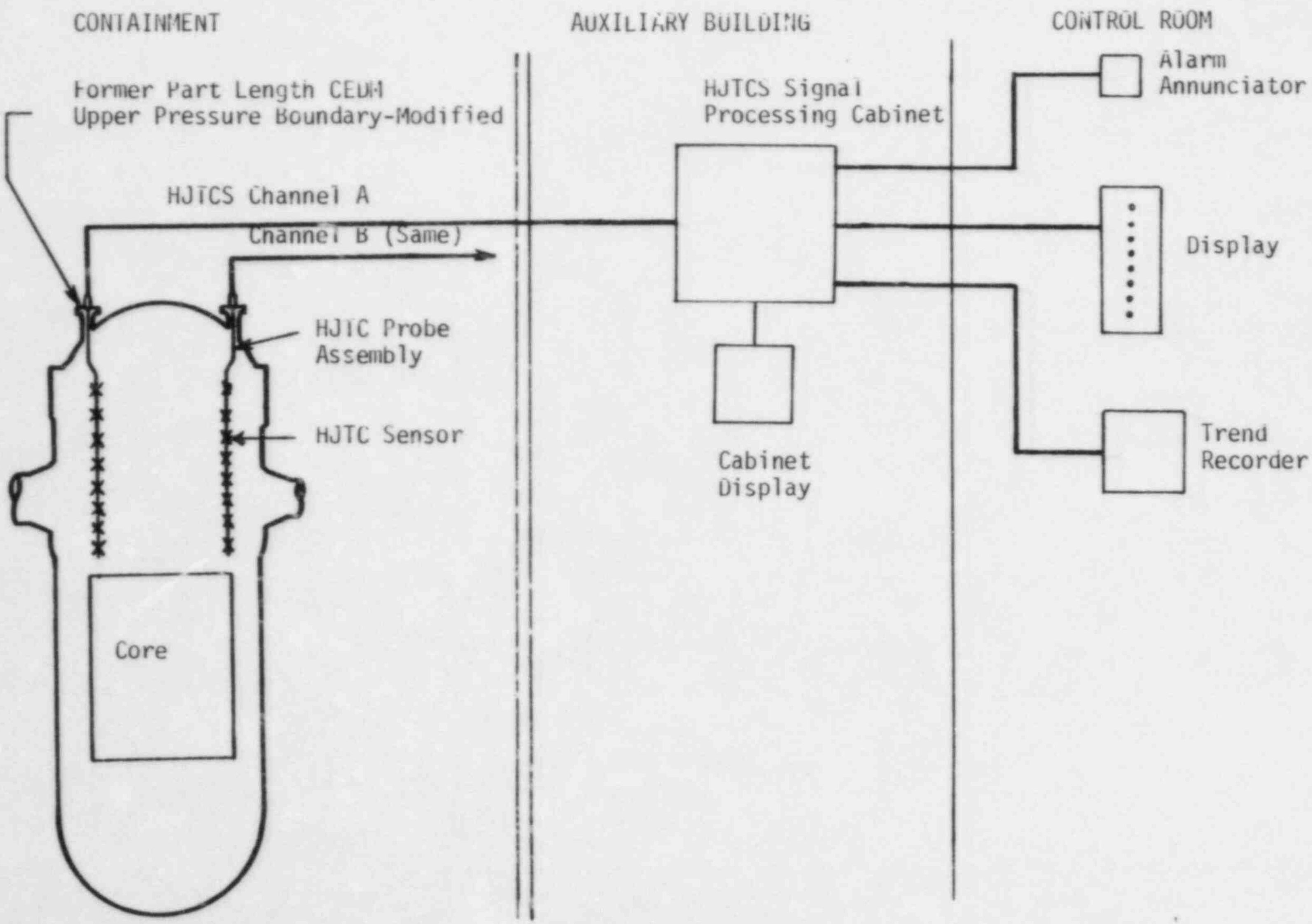


FIGURE 3-1
HJTCS SENSORS, PROCESSING AND DISPLAY

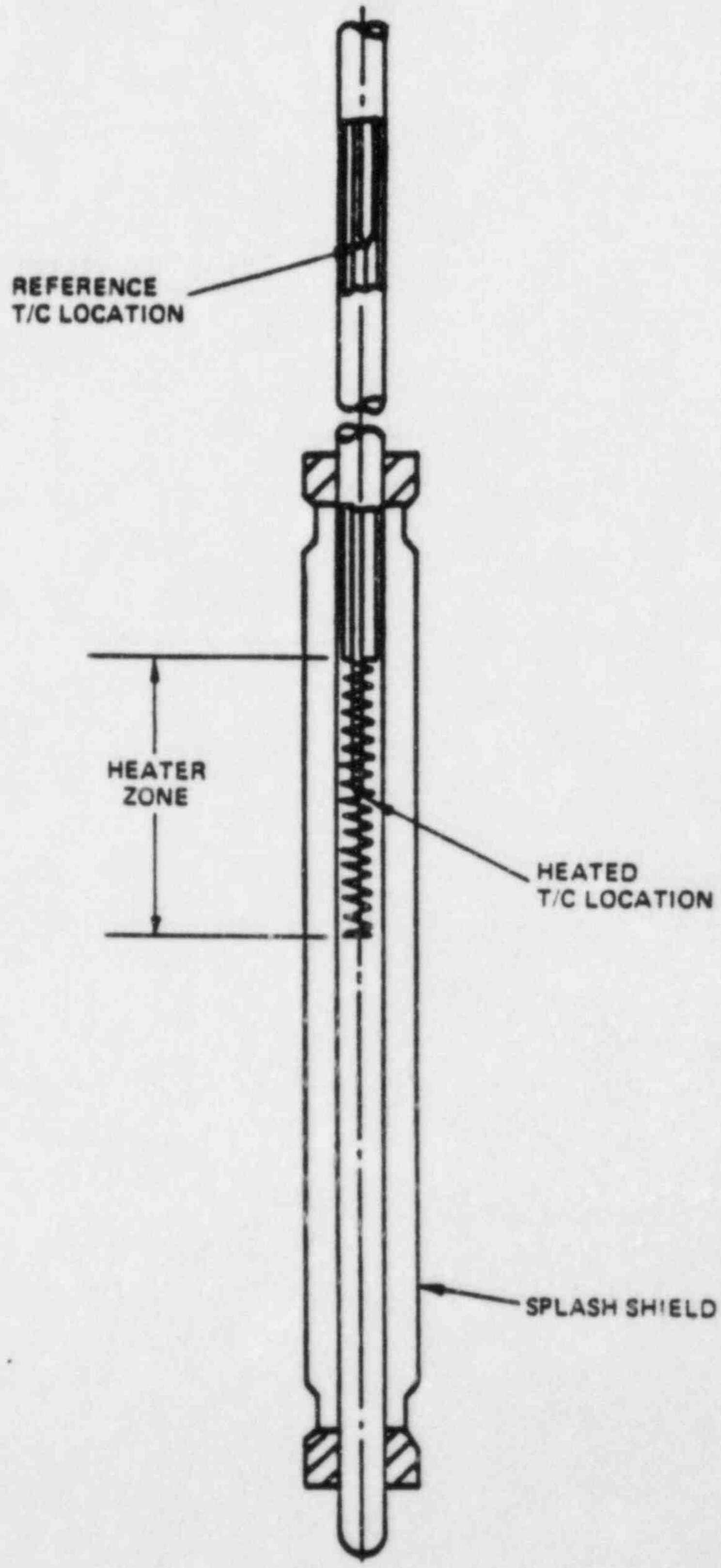


FIGURE 3-2

HJTC SENSOR WITH SPLASH SHIELD

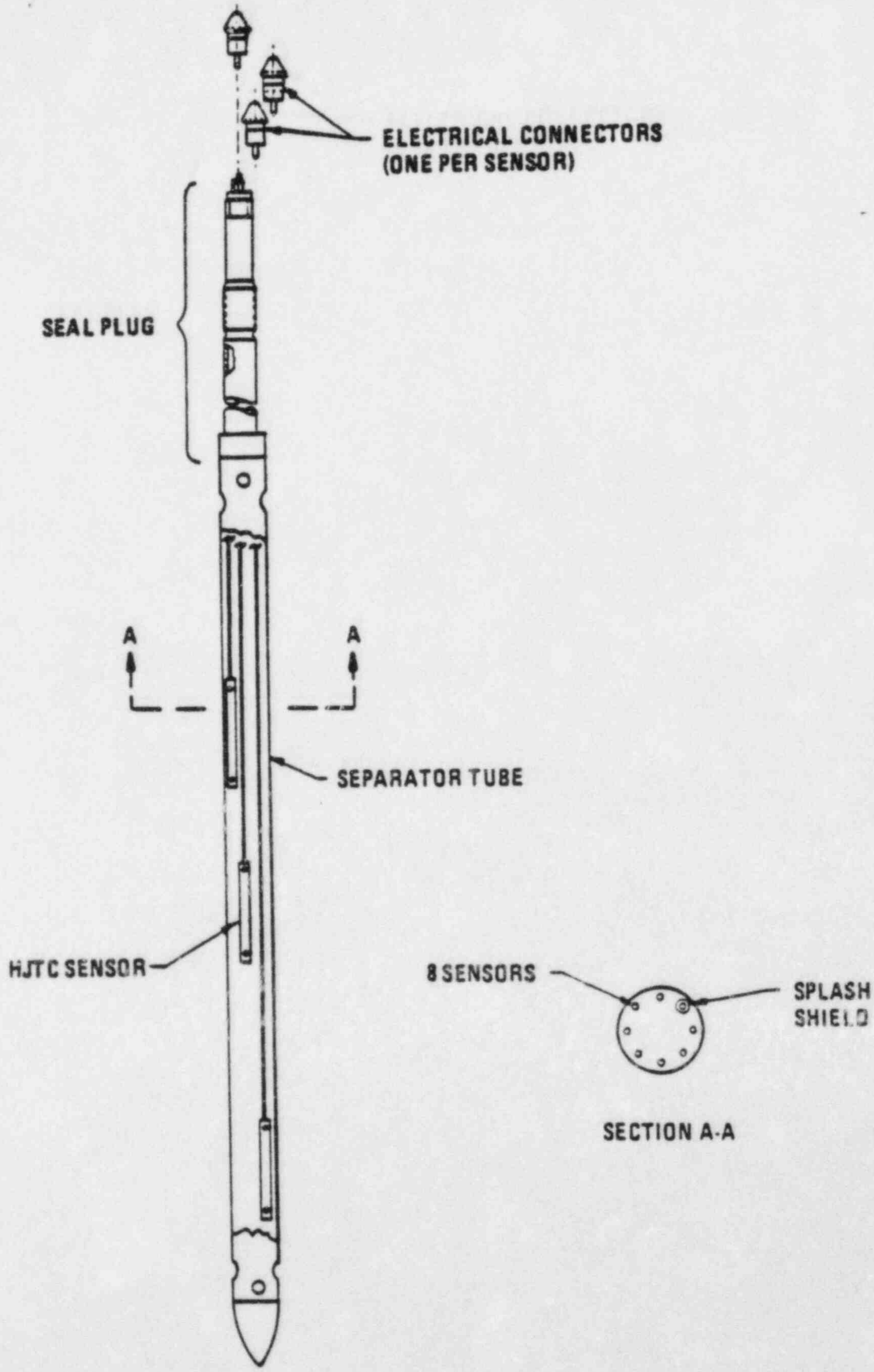


FIGURE 3-3
HJTC PROBE ASSEMBLY

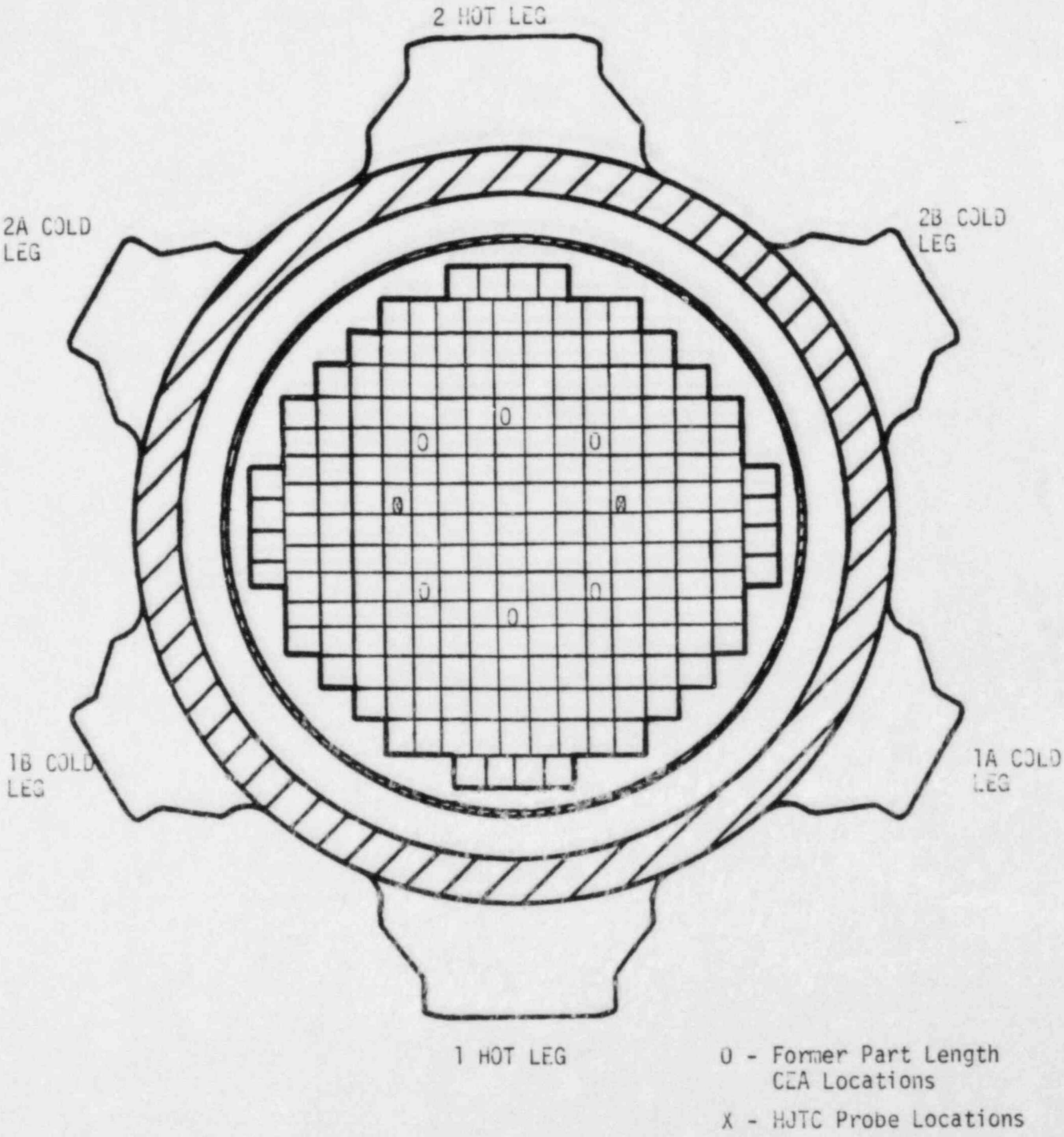


FIGURE 3-4
HJTC PROBE LOCATION

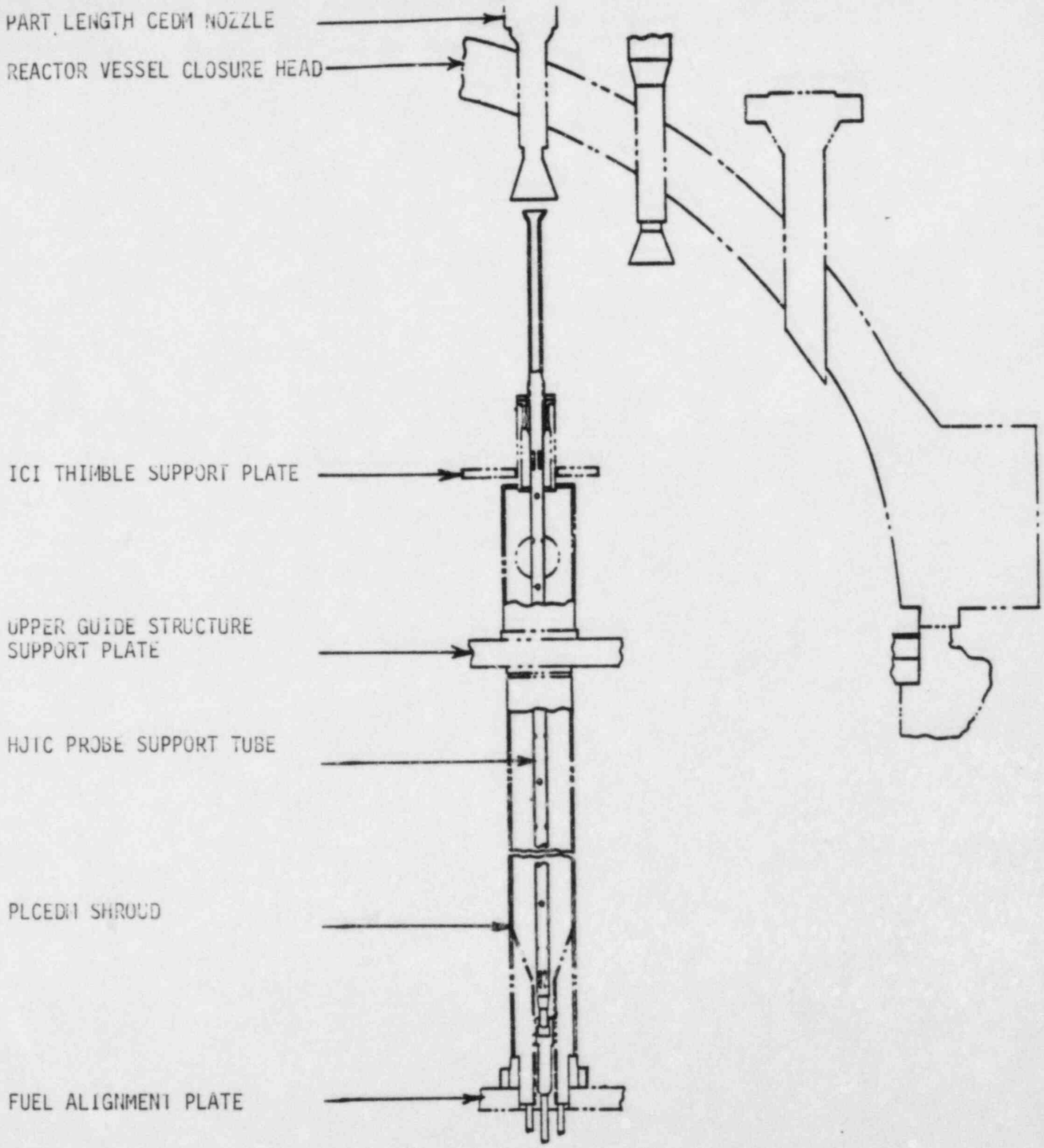
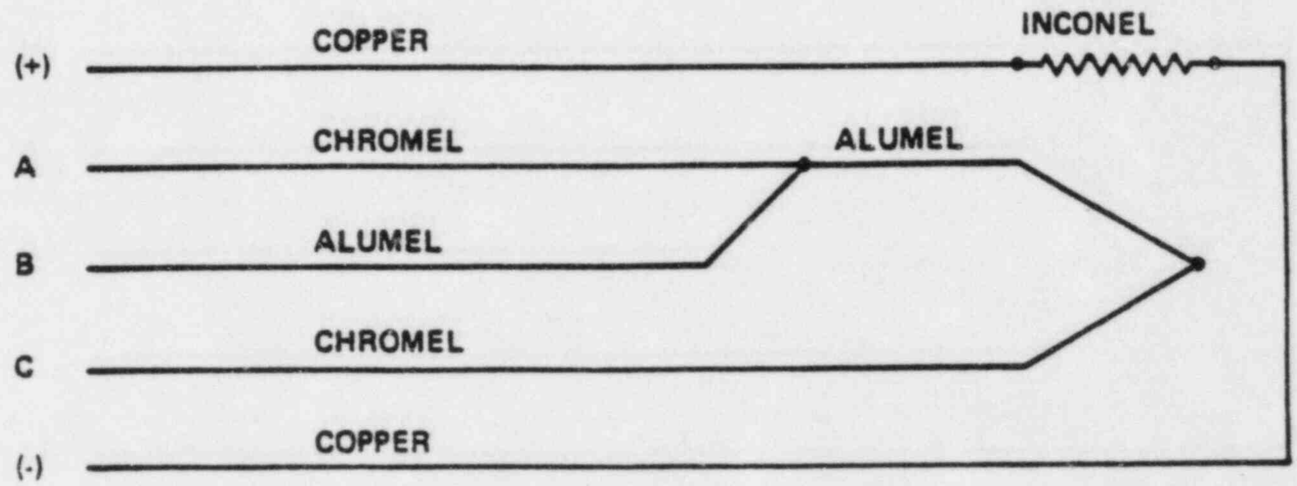


FIGURE 3-5
HJTC PROBE SUPPORT TUBE ASSEMBLY



V (A - B) = ABSOLUTE TEMPERATURE, UNHEATED JUNCTION
V (C - B) = ABSOLUTE TEMPERATURE, HEATED JUNCTION
V (A - C) = DIFFERENTIAL TEMPERATURE

FIGURE 3-6

HJTC SENSOR ELECTRICAL DIAGRAM

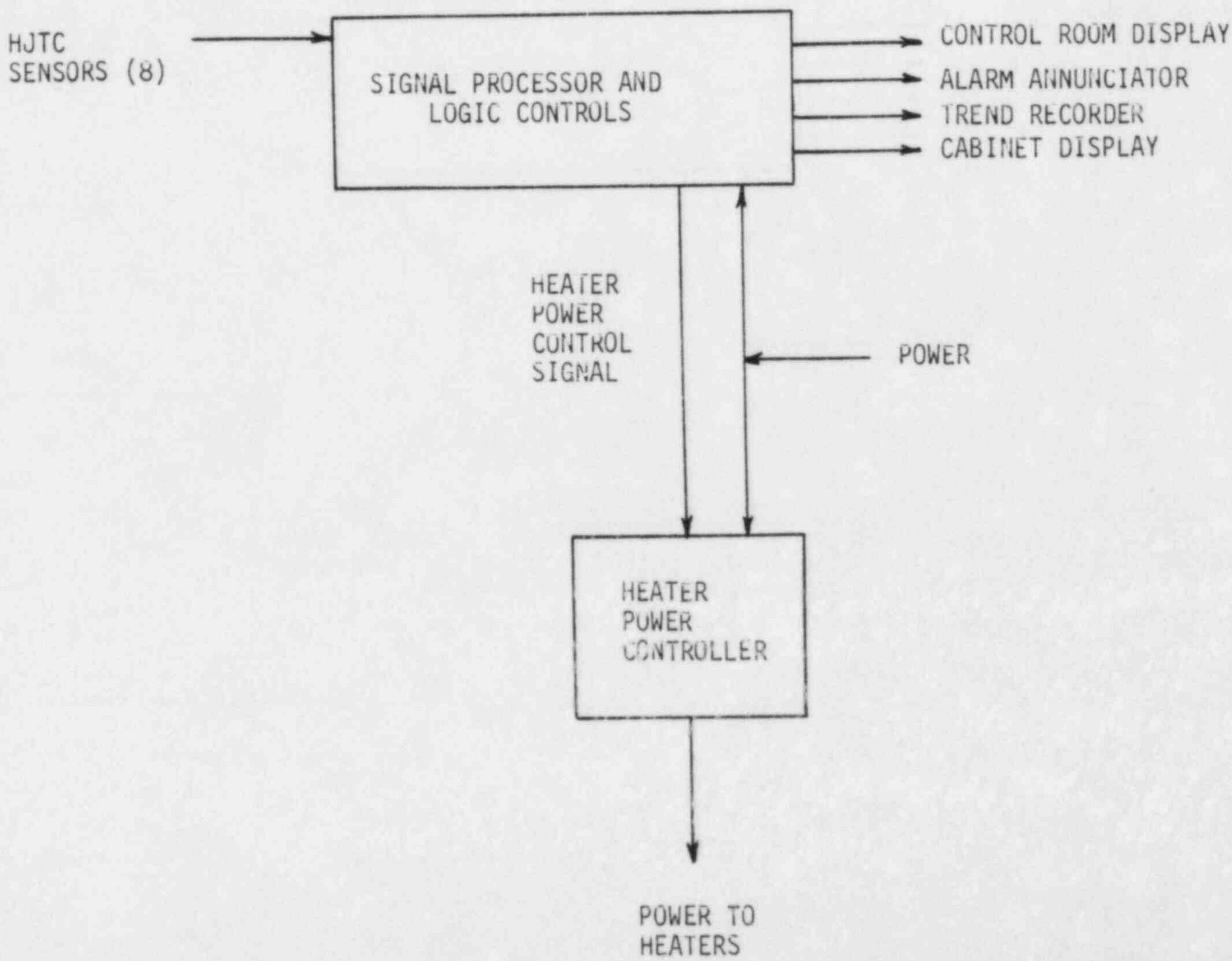


FIGURE 3-7

HJTCS PROCESSING CONFIGURATION
(ONE CHANNEL SHOWN)

NRC GENERIC LETTER 82-28 CHECKLIST
NUREG-0737, ITEM II.F.2., REQUIREMENTS
REACTOR VESSEL LEVEL MONITORING SYSTEM

For: Calvert Cliffs Nuclear Power Plant, Units 1 & 2

Docket Nos.: 50-317 and 50-318

Operated By: Baltimore Gas and Electirc Company

Item	Reference (Sections refer to this report)	Deviations	Schedule
1. Description of the proposed system including:			
a. a final design description of additional instrumentation and displays;	Section 3	Yes-Note 1	Complete
b. detailed description of existing instrumentation systems;	G	No	Complete
c. description of completed or planned modifications.	Section 3	No	Complete
2. A design analysis and evaluation of inventory trend instrumentation, and test data to support design in item 1.	Sections 2 & 4	No	Complete
3. Description of tests planned and results of tests completed for evaluation, qualification, and calibration of additional instrumentation.	Sections 4 & 5	No	Complete
4. Provide a table or description covering the evaluation of conformance with NUREG-0737; II.F.2, Attachment 1, and Appendix B (to be reviewed on a plant specific basis)	For Reactor Vessel Level Monitoring System only Sections 1 & 2	No	Complete

5. Describe computer, software and display functions associated with ICC monitoring in the plant.	Sections 2 & 3	Yes - Note 1	Complete
6. Provide a proposed schedule for installation, testing, and calibration and implementation of any proposed new instrumentation or information displays.	Sections 4 & 5	No	Complete
7. Describe guidelines for use of reactor coolant inventory tracking system, and analyses used to develop procedures.	Section 6	No	Complete
8. Operator instructions in emergency operating procedures for ICC and how these procedures will be modified when final monitoring system is implemented.	Section 6	No	Complete
9. Provide a schedule for additional submittals required			
C-E HJTC System			
Discuss the spacing of the sensors from the core alignment plate to the top of the reactor vessel head. How would the decrease in resolution due to the loss of a single sensor affect the ability of th system to detect an approach to ICC?	I & D and Sections 2.2 and 3.1	No	Complete

NRC Generic Letter 82-28 Checklist
Appendix B (of NUREG-0737, II.F.2) Requirements
Reactor Vessel Level Monitoring System

Item	Reference	Deviations
1. Environmental qualification	Section 5	No
2. Single failure analysis	I & D Sections 2.2 & 3.1	No
3. Class 1E power source	Section 3.2	No
4. Availability prior to an accident	I, D + L	No
5. Quality Assurance	O, H	No
6. Continuous indications	Section 3	No
7. Recording of instrument outputs	Section 3.3.1	No
8. Identification of instruments	Section 3	No
9. Isolation	Section 3	No

Note to Attachment (1)

(1) The BG&E reactor vessel level monitoring system (RVLMS) differs from the C-E generic heated junction thermocouple system (HJTCS) in terms of the control room display. The BG&E RVLMS includes a light array in the control room for each HJTCS channel, to indicate HJTC sensor being covered or uncovered; whereas the generic C-E HJTCS would provide a digital display for each channel. The BG&E RVLMS considers the control board mounted Class 1E display as a backup display, with the primary display design being developed as part of the plant's safety parameter display system (SPDS). SPDS information will be provided as part of BG&E's response to NRC Generic Letter 82-33.

Baltimore Gas and Electric Company
Calvert Cliffs Nuclear Power Plant
Untis 1 and 2
Reactor Vessel Level Monitoring System
Licensing Re ort

April, 1984

REFERENCES

(A) Letter from D.G. Eisenhut (NRC) to All Licensees of Operating Westinghouse and C-E PWRs (Except Arkansas Nuclear One-Unit 2 and San Onofre Units 2 and 3, Dated December 10, 1982, Inadequate Core Cooling Instrumentation System (Generic Letter No. 82-28).

(B) Letter from A.E. Lundvall, Jr. (BG&E) to D.G. Eisenhut (NRC), Dated December 31, 1981, "Calvert Cliffs Nuclear Power Plant, Units 1 & 2, Docket Nos. 50-317 and 50-318, Response to NUREG-0737

(C) CEN-185, "Documentation of Inadequate Core Cooling Instrumentation for Combustion Engineering Nuclear Steam Supply Systems," Combustion Engineering, September, 1981.

(D) CEN-181, "Generic Response to NRC Questions on the C-E Inadequate Core Cooling Instrumentation," Combustion Engineering, September 1981.

(E) Letter from A.E. Lundvall, Jr. (BG&E) to J.R. Miller (NRC), Dated August 30, 1983, "Calvert Cliffs Nuclear Power Plant, Units Nos. 1 & 2; Dockets Nos. 50-317 and 50-318, Reactor Vessel Level Monitoring System".

(F) Letter from A.E. Lundvall, Jr. (BG&E) to J.R. Miller (NRC), Dated October 26, 1983, "Calvert Cliffs Nuclear Power Plant, Units Nos. 1 & 2; Dockets Nos. 50-317 and 50-318, Reactor Vessel Level Monitoring System".

(G) CEN-117, "Inadequate Core Cooling - A Response to NRC IE Bulletin 79-06C, Item 5 for Combustion Engineering Nuclear Steam Supply Systems," Combustion Engineering, October, 1979.

(H) CENPD-210-A, Revision 3, "Quality Assurance Program, A Description of the C-E Nuclear Steam Supply System Quality Assurance Program," Combustion Engineering, November, 1977.

(I) Letter from K.P. Baskin (CEOG) to D.M. Crutchfield (NRC), dated June 1, 1982, "Response to Questions on C-E Heated Junction Thermocouple."

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REFERENCES (continued).

(J) CEN-185, Suppl. 1, "HJTC Phase 1 Test Report," Combustion Engineering, November 1981.

(K) CEN-185P, Suppl. 2-P, "HJTC Phase 2 Test Report," Combustion Engineering, November 1981.

(L) CEN-185P, Suppl. 3-P, "Heated Junction Thermocouple, Phase III Test Report," Combustion Engineering, September 1982.

(M) CEN-99(S), "Seismic Qualification of NSSS Supplied Instrumentation Equipment," Combustion Engineering, August 1978.

(N) CENPD-255-A, Revision 03, "Environmental Qualification of Class 1E Electrical Equipment," Combustion Engineering, December 1983.

(O) BG&E Calvert Cliffs Nuclear Power Plant Units 1 and 2, Updated Final Safety Analysis Report, Section 1B - Quality Assurance Program.