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R. J. GARY
EXECUTIVE VICE PRESIDENT
AND GENERAL MANAGER

January 3, 1984

Director of Nuclear Reactor Regulation
Attention: Mr. B. J. Youngblood, Chief
Licensing Branch No. 1
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUBJECT: COMANCHE PEAK STEAM ELECTRIC STATION
DOCKET NOS. 50-445 AND 50-446
COMPLIANCE WITH TMI ACTION PLAN ITEM II.F.2

REF: B. J. Youngblood letter to R. J. Gary of October 7, 1983

Dear Sir:

The referenced letter requested that TU provide additional information concerning TMI Action Plan Item II.F.2, "Instrumentation for Detection of Inadequate Core Cooling" and the justification for the proposed implementation schedule for the Heated Junction Thermocouple (HJTC) System. The requested information is hereby submitted in the attached report which was prepared in response to the referenced request.

It should be noted that the implementation of the Comanche Peak Steam Electric Station (CPSES) instrumentation for detection of inadequate core cooling will be completed prior to fuel load except for the HJTC System. The implementation of the HJTC System is scheduled for prior to startup following the first refueling outage.

The backfits required by all the NUREG-0737 items are part of an NRC staff plan to improve safety at power reactors. Just as operating plants have been allowed to continue operation while NUREG-0737 items are being implemented, CPSES should be issued an Operating License and allowed to operate while reasonable efforts are expended to implement applicable and appropriate NUREG-0737 items. Specifically, CPSES should be issued an operating license and allowed to operate while implementation of the HJTC System continues.

Respectfully,

R. J. Gary

R. J. Gary

DRW/grr

B001

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TEXAS UTILITIES SERVICES INC.

COMANCHE PEAK STEAM ELECTRIC STATION

RESPONSE TO NUREG-0737 ITEM II.F.2

INSTRUMENTATION FOR DETECTION OF INADEQUATE CORE COOLING

December 5, 1983

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1.0 INTRODUCTION

This report responds to the documentation requirements of NUREG-0737 Item II.F.2, "Instrumentation for Detection of Inadequate Core Cooling." The report describes (1) the instrumentation system to be used at the Comanche Peak Steam Electric Station (CPSES) for monitoring of inadequate core cooling (ICC) conditons, (2) the status of implementation of the system, and (3) the status of conformance to the associated system requirements.

Functional design requirements of the ICC monitoring system are described in Section 2.0. Section 3.0 provides a final design description of the system instrumentation and its various functional components. The methods in which the system will be applied for operator use at CPSES are briefly described in Section 4.0. The proposed system implementation status is discussed in Section 5.0. The status of conformance to system description documentation requirements is delineated in Section 6.0.

2.0 SYSTEM FUNCTIONS

The principal function of the Inadequate Core Cooling (ICC) monitoring instrumentation system is to provide redundant capability to monitor the approach to, existence of and recovery from ICC. The system is designed to provide the reactor operator with clear, easy-to-interpret indications of reactor coolant inventory conditions during the various developmental stages of any transient event which progresses slowly enough such that ICC can be avoided by operator intervention. Thus, use of the system is limited primarily to slow-transient conditions similar to those postulated to occur in conjunction with a small break loss of coolant accident (LOCA). A small break LOCA is considered to be any rupture of the reactor coolant system (RCS) pressure boundary having a total cross-sectional area less than 6.0 in^2 and causing reduction in pressurizer liquid level and pressure beyond the restoration capacity of the normal charging system.

2.1 Definition of ICC

For purposes of discussion in this report, ICC is defined as a high-temperature condition anywhere within the active reactor core requiring operator action to restore cooling before core damage occurs. In accordance with 10CFR50.46(b)(1), an acceptable criterion for the inception of ICC is a calculated maximum fuel element cladding temperature in excess of 2200°F. Time allowance for decisive operator interaction to prevent ICC, in contrast to automatic actuation of Engineering Safeguard Features (ESF's), requires that the system transient conditions fall within the typical range of limited consequences due to a small break LOCA. Therefore, the functional requirements of the ICC monitoring system apply primarily to small break LOCA events, with the added consideration that the system will survive more rapid transient conditions (i.e., a large break LOCA) in order to monitor subsequent post-accident recovery.

Analyses described in Section 15.6 of the CPSES FSAR indicate that the calculated maximum fuel element cladding temperature for any postulated small break LOCA would not exceed 1800°F. Therefore, it is not expected that a small break LOCA could lead to a condition of ICC since multiple system failures would be required (e.g., loss of all high pressure safety injection in addition to the small break LOCA). However, for purposes of ICC monitoring system design and evaluation, it has been assumed that functional requirements include the full sequence of conditions from the onset of a small break LOCA during normal reactor operation, through the gradual loss of coolant inventory, leading to and causing ICC, to restoration of core cooling and subsequent coolant recirculation under stable, controlled conditions. The assumed successive stages in the progression of an ICC event are defined in Table I.

TABLE I. STAGES IN PROGRESSION OF ICC EVENT

Stage No.	Coolant Inventory Conditions	ICC Phase	Description	Bounding Condition
1	Decreasing	Approach to	Depressurization of RCS and loss of subcooling	Occurrence of coolant saturation
2	Decreasing	Approach to	Increasing voids in upper plenum; descreasing two-phase mixture level above core	Initiation of core uncovery
3	Decreasing	Approach to or Existence of	Decreasing two-phase mixture level in core; increasing core temperatures	Minimum covery of core
4	Increasing	Recovery from	Increasing two-phase mixture level in core; restoration of core cooling	Completion of core recovery
5	Increasing	Recovery from	Increasing two-phase mixture level above core	Vessel refilled
6	Stable	Recovery from	Coolant inventory restored; existence of stable, controlled conditions	Long-term forced recirculation

2.2 Functional Requirements

To provide redundant monitoring capability over the entire range of conditions during an ICC event, the selected parameters to be monitored at CPSES are the primary RCS saturation margin (representative of the degree of subcooling), the "collapsed" water level in the reactor vessel upper head and plenum regions (representative of RCS inventory), and the RCS temperature at various core exit locations (representative of core temperatures). At the onset of a small break LOCA, an indication of reduced margin to saturation (loss of subcooling) will provide the earliest advance warning of impending conditions which could lead to ICC. The resulting occurrence of saturation conditions will mark the end of Stage 1 (see Table I) and the beginning of Stage 2 in the event progression.

During Stage 2, voids will occur in the upper head and plenum regions due to continued loss of coolant mass. The corresponding reduction in collapsed water level in these regions will indicate the extent of coolant loss and the trend of changes in coolant inventory prior to potential core uncovery. If the event is allowed to progress, core uncovery will occur (Stage 3).

The beginning of Stage 3 does not immediately imply the existence of ICC conditions. As the decreasing level of the two-phase steam/water mixture (or froth region) falls below the top of the active core (just below the monitoring range of collapsed water level in the upper plenum), adequate core cooling will continue as long as the top of the froth region covers the top of the core. Overheating of the core will begin only when the froth region falls below the top of the core. The extent of overheating will be indicated by the monitored core exit temperatures. Analyses described in Ref. 1 lead to the conclusion that a core exit temperature reading of 1200°F is a satisfactory criterion for determining whether the threshold of impending ICC has been reached. This criterion is assumed to safely represent maximum fuel cladding temperatures which are lower than the minimum criterion (2200°F) for the existence of ICC.

The beginning of Stage 4, the start of recovery from ICC, is marked by the change to a continuous increase in two-phase mixture level due to the addition of safety injection water. This reversal in the trend of coolant inventory conditions will be indicated by a return from superheated to saturated or subcooled conditions and by a reduction in core exit temperatures. Complete recovery of the core, the initiation of Stage 5, will be indicated by the restoration of monitored collapsed water level in the upper plenum. When the collapsed water level reaches the maximum, corresponding to full restoration of reactor coolant inventory to the level required for continuous recirculation, Stage 6 of the ICC event will begin. This final stage represents the sustained existence of stable, controlled reactor cooling conditions. After this stage is accomplished, all ICC monitoring parameters should give continous indication of these stable conditions.

3.0 INSTRUMENTATION DESCRIPTION

The ICC monitoring system at CPSES employs two separate types of instrumentation systems to monitor the parameters discussed above. The Core Cooling Monitor (CCM) instrumentation system is designed to perform two functions. Output from this system provides indication of the reactor coolant temperature at various core exit locations and also indicates the RCS saturation margin. The Heated Junction Thermocouple (HJTC) instrumentation system is employed to monitor the collapsed water level in the upper head and plenum regions of the reactor vessel. These instrumentation systems are described below.

3.1 Core Cooling Monitor System

Two qualified, redundant CCM's are used for ICC monitoring in each reactor unit at CPSES. Each CCM is designed to indicate core exit thermocouple temperatures (CET function) and to monitor the RCS saturation margin (SMM function).

3.1.1 Core Exit Thermocouples

To provide input temperature data to the CCM microprocessor, the NSSS-supplied array of fifty CET's have been divided into two separate, redundant trains with each set of CET's having a distribution representative of all four quadrants of the reactor core exit area. The planar locations of the CET's with respect to core fuel assembly position are illustrated in Fig. 1. All CET's are axially located just above the Upper Core Plate as illustrated in Fig. 2. Also illustrated in Figs. 1 and 2 are the relative locations of the HJTC probe assemblies and corresponding sensor positions, respectively, which are described later.

Each CET is a Type K (chromel-alumel) thermocouple contained within an aluminum-oxide insulated, stainless steel sheathed cable (1/8-in. OD). Each cable passes through one of four vessel head penetrations (located 90 degrees apart and near the core periphery) which contain pressure-boundary sealing assemblies. Figure 1 includes indication of the head penetration assignments for the various thermocouple cables, separated into groups of either twelve or thirteen cables per penetration.

Above the vessel head, the CET cables are grouped into two separate trains. Each train is routed to a separate reference junction box which contains three platinum resistance temperature detectors (RTD's) for reference temperature measurements. These reference measurements permit the transition from chromel-alumel leads to copper conductors for signal transmission to the CCM microprocessor.

The CET signals are used in the CCM to monitor coolant temperatures over the entire range including normal operation conditions and extending to beyond accident extremes. The design input/output useful range limits and system accuracy are listed Table II. Each thermocouple is periodically checked for open or shorted conditions, and the signal is adjusted to account for the in-containment cold reference junction conditions based on the reference RTD measurements. The highest, valid CET signal is displayed on the Control Board and is also employed by the microprocessor to determine the RCS saturation margin.

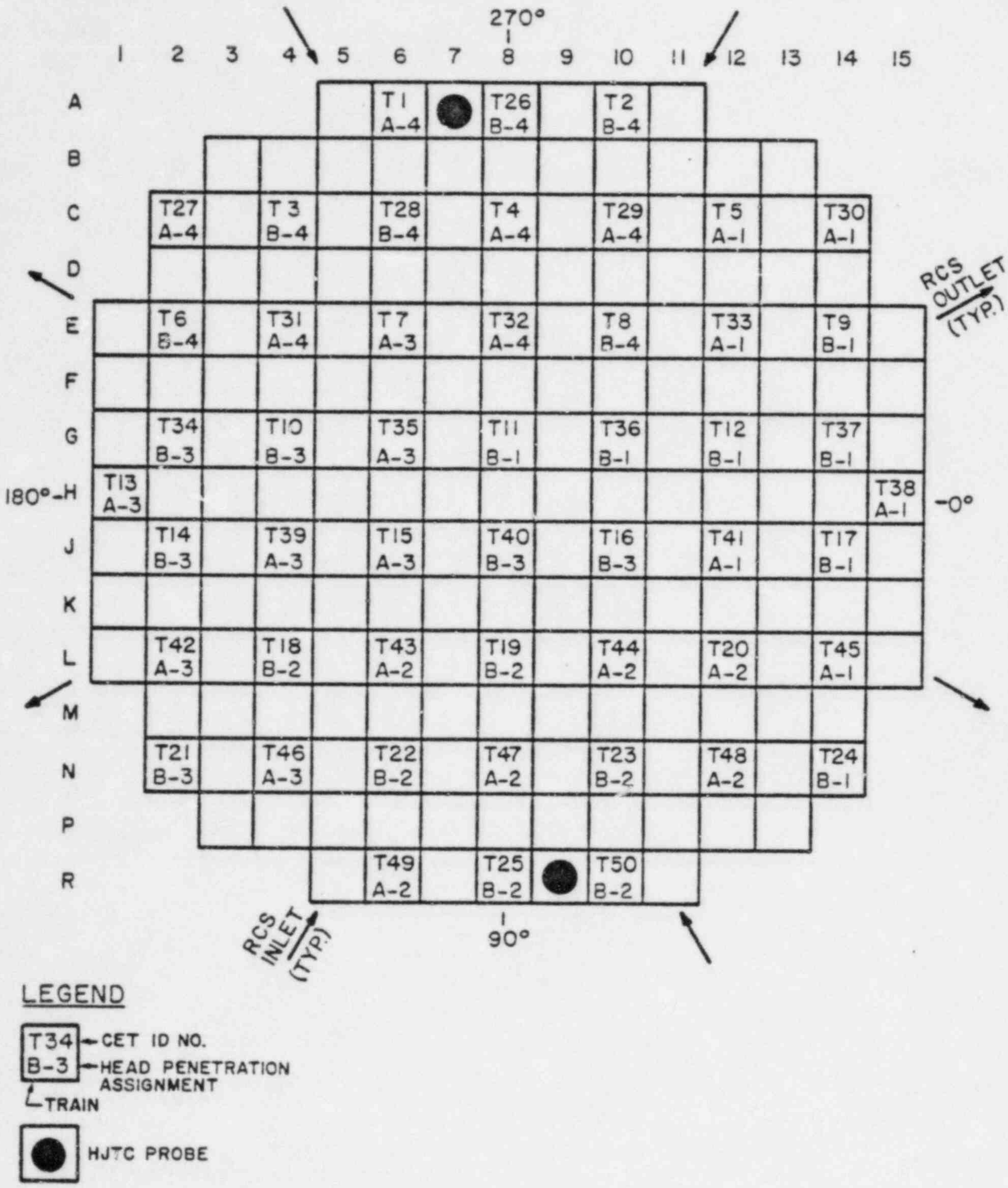

FIG. 1 CORE EXIT THERMOCOUPLE AND HEATED JUNCTION THERMOCOUPLE LOCATIONS (PLAN VIEW)

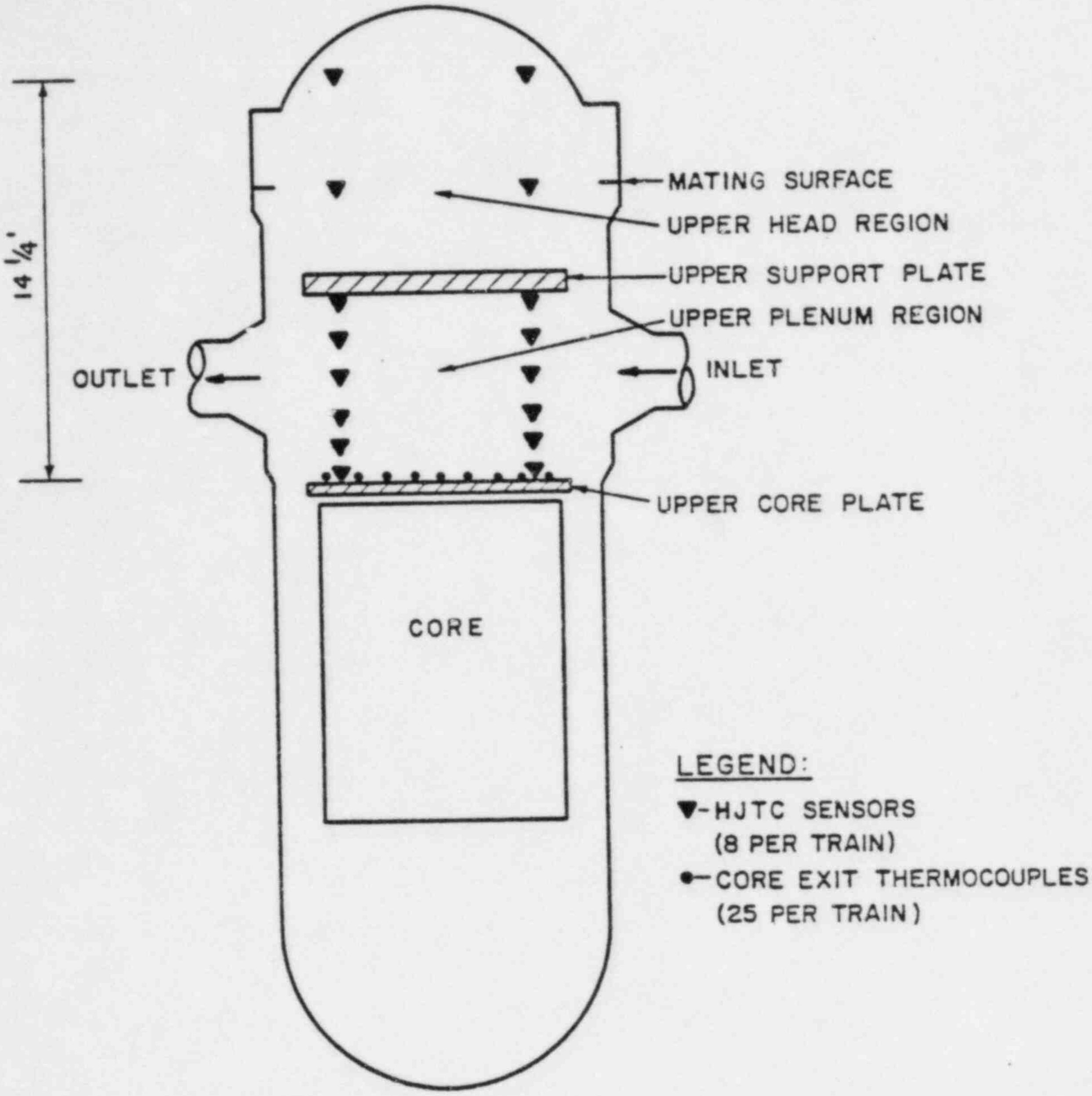

FIG. 2 CORE EXIT THERMOCOUPLE AND HEATED JUNCTION THERMOCOUPLE LOCATIONS (ELEVATION VIEW)

TABLE II. CORE COOLING MONITOR SIGNAL SPECIFICATION SUMMARY

PARAMETER	NO. PER TRAIN	RANGE DESCRIPTION
Input:		
Coolant Pressure	1	0 - 1700 PSIG
Pressurizer Pressure	1	1700 - 2500 PSIG
Hot Leg Temperature	2	50 - 695°F
Cold Leg Temperature	2	50 - 695°F
Core Exit T/C Temperature	25	50 - 2300°F
Cold Junction Temperature	3	50 - 500°F
Output:		
Saturation Margin	1	300°F Subcool to 300°F Superheat
Highest Core Exit T/C	1	50 - 2300°F
Signal Data Sets	2	Engineering Units
System:		
Accuracy		±2.5°F
Resolution		0.1°F

3.1.2. Saturation Margin Monitor

In addition to the highest CET temperature, the SMM function of the CCM makes use of various other RCS measurements for which signal flow paths are indicated in Figures 3 and 4. Also indicated in Figures 3 and 4 are the signal flow paths from the HJTC instruments described later. Redundant, diverse temperature measurements are provided by RTD's located such that each SMM train employs the hot or cold leg RCS temperature from each of the four reactor coolant loops. As illustrated in Fig. 3, Train A employs the hot leg temperatures from Loops 1 and 2 and the cold leg temperatures from Loops 3 and 4; Train B employs the cold leg temperatures from Loops 1 and 2 and the hot leg temperatures from Loops 3 and 4. Also employed are the hot leg RCS wide-range pressure measurements (Loop 1 for Train A and Loop 4 for Train B) and redundant narrow-range pressurizer pressure measurements. These temperature and pressure measurements are used in conjunction with a stored steam-table algorithm to compute the saturation margin. Conservatively, the computation is based upon the highest valid RCS temperature and the lowest valid RCS pressure. Thus, under normal operating subcooled conditions, the SMM output signal represents the minimum possible margin to saturation. In the event of depressurization due to a small break LOCA, this output signal will provide the earliest indication of the existence of saturation conditions.

3.2 Heated Junction Thermocouple System

To provide redundant capability for measurement of the reactor coolant inventory in the upper head and plenum regions of the reactor vessel, CPSES is in the process of installing a Heated Junction Thermocouple (HJTC) system supplied by Combustion Engineering, Inc. (C-E). Functionally, this system represents a selected alternative to the commonly-referenced Reactor Vessel Level Indicating System (RVLIS). It is also synonymous to the sometimes referenced Reactor Vessel Level Monitoring System (RVLMS). The principal function of the HJTC system is to obtain an unambiguous, direct indication of the existence of coolant voids (and hence an indication of reduced RCS coolant inventory) in the vessel space above the reactor core. The HJTC measurements will assist in the timely detection of the approach to ICC and subsequent restoration of optimal core cooling in the event that an ICC condition should occur.

The basic measuring device of the HJTC system is a probe assembly consisting of a number of thermocouple sensors with individual splash shields distributed axially at selected locations inside a separator tube. The purpose of the separator tube is to create a single-phase collapsed water level inside the tube while a steam-water two-phase mixture may exist in the surrounding medium outside the tube. Each sensor consists of two chromel-alumel thermocouple junctions positioned approximately 4.5 inches apart, the lower one of which is heated by an inconel electric coil. Figure 5 illustrates the electrical arrangement of an HJTC sensor. The principle of measurement corresponds to the temperature differential between the heated and unheated thermocouple junctions as affected by the heat transfer characteristics of the sensor-immersion medium inside the separator tube. In a normal operating state where the sensor is immersed in a subcooled liquid medium (water), the temperature difference is quite small (<<100°F) due to the relatively high heat transfer capability of water. However, when the collapsed water level falls below the heated junction, the reduced heat transfer capability of the surrounding medium (containing steam) causes the

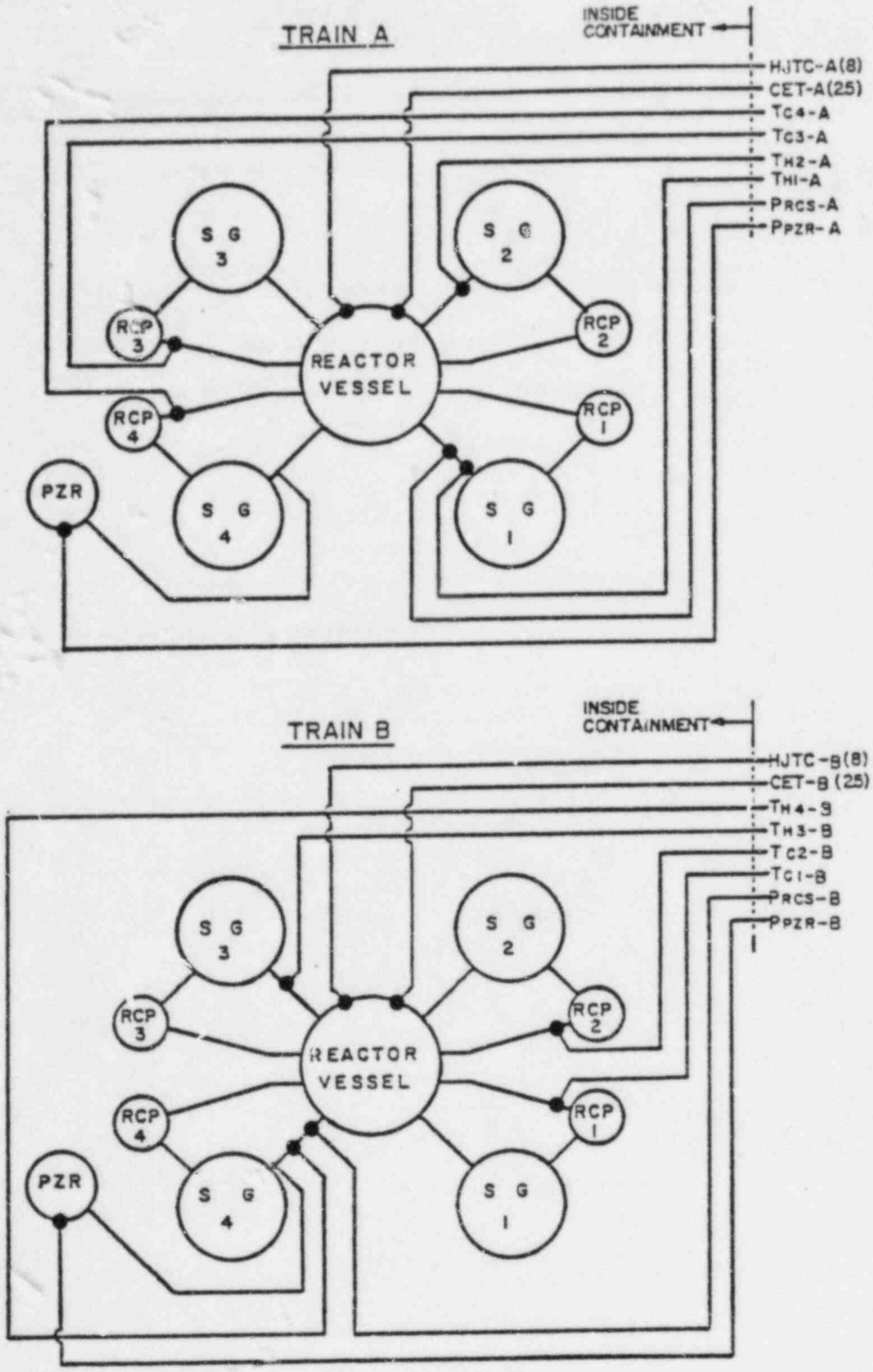

FIG. 3 ICC MONITORING SYSTEM SENSOR LOCATIONS

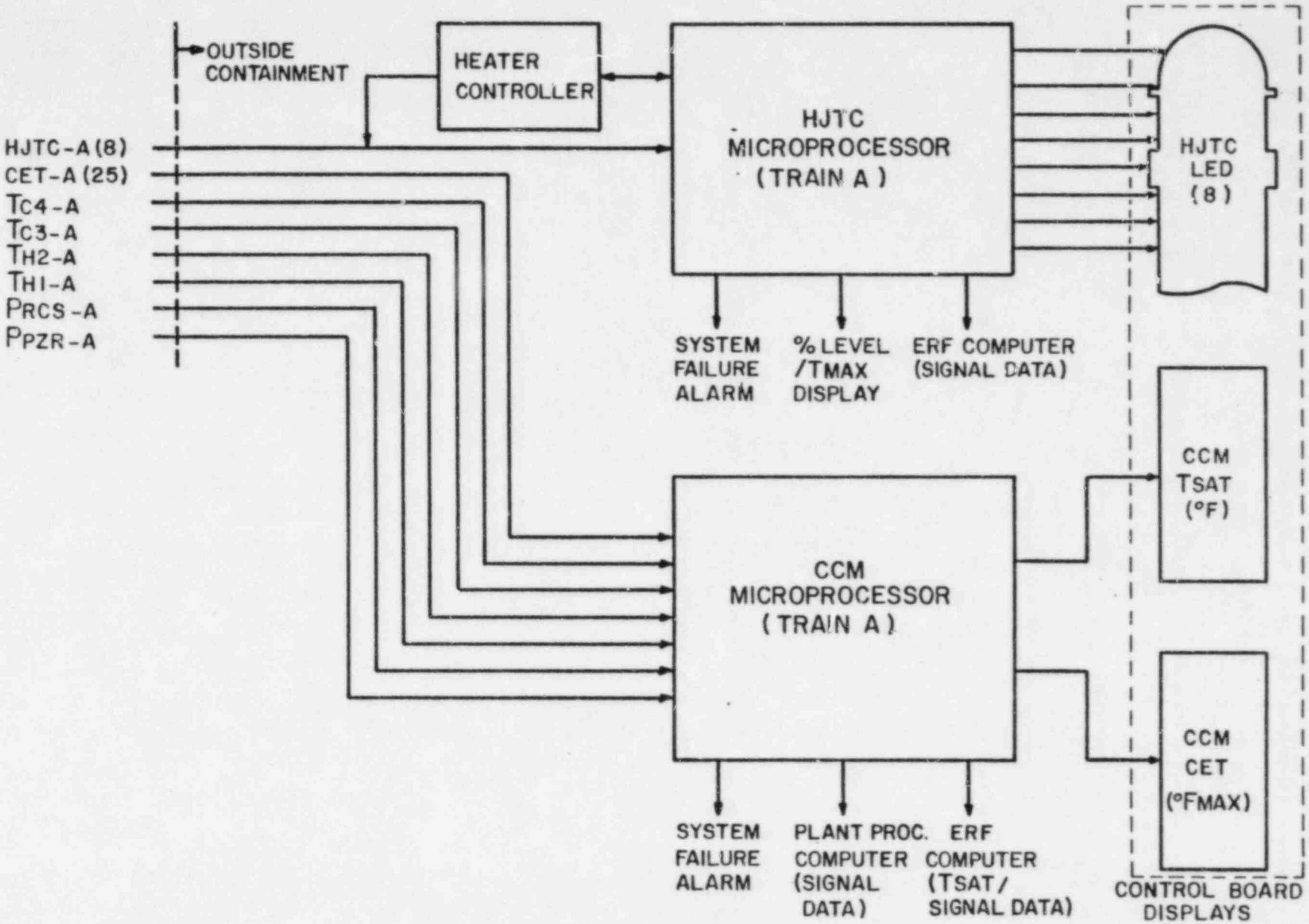

FIG. 4 ICC MONITORING SYSTEM TRAIN A SIGNAL PROCESSING AND DISPLAYS (TRAIN B SIMILAR)

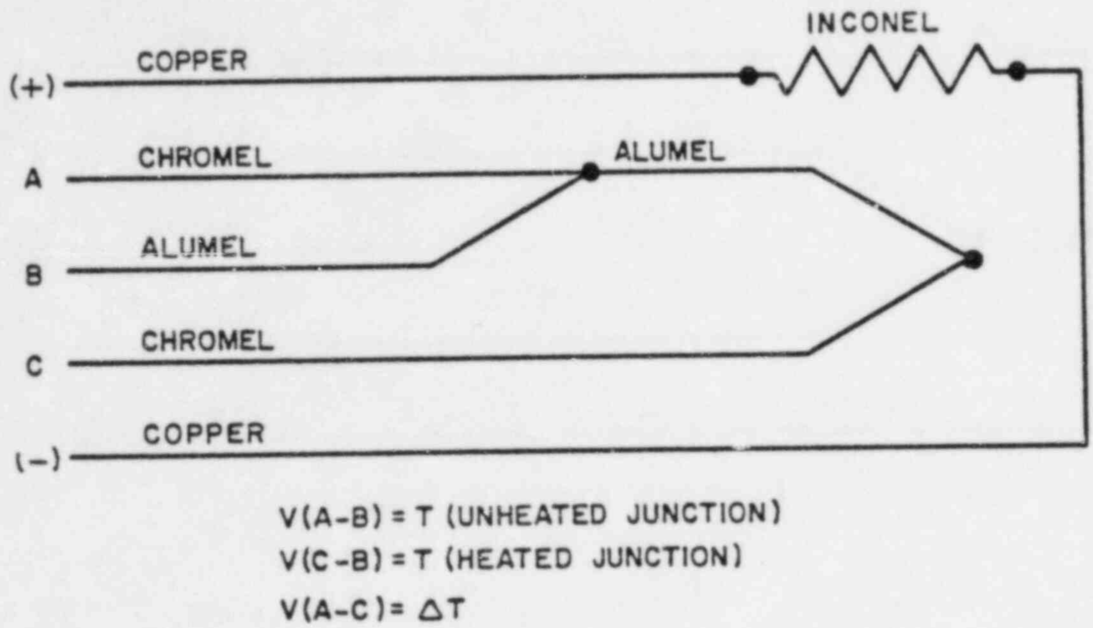

FIG. 5 HJTC SENSOR ELECTRICAL DIAGRAM

temperature at the bottom of the sensor to rise, producing a much larger temperature difference (as much as several hundred degrees). Thus, the measured temperature difference, ΔT, provides direct indication of the presence of water voids in the sensor-immersion medium. Changes in reactor coolant inventory above the reactor core can be monitored based on results obtained from the local, direct measurements by different sensors within the probe assembly.

In addition to the thermocouple differential temperature, the system design output information provides separately the unheated junction temperature, indicative of the local reactor coolant temperature, and the heated junction temperature which is used for control of power to the heater coil.

As illustrated in Figures 3 and 4, the output signals from each HJTC sensor are transmitted by a five-wire cable (two chromel plus one alumel thermocouple and two copper heater power wires) leading from the probe assembly to microprocessor-based control equipment located in the Control Room. Cold junction compensation and analog-to-digital conversion are performed on the thermocouple signals. In addition to the heated junction, unheated junction and differential temperatures, the microprocessor output signals include the heater controller setpoint (regulating sensor sensitivity), the auctioneered highest reactor coolant temperature in the upper head region, and the computed reactor coolant inventories (% level) in the upper head and plenum regions. Also included are separate condition status signals indicating whether each sensor is covered (in a liquid medium) or is uncovered (in a vapor medium). These data are all transmitted in full duplex digital form to the CPSES Emergency Response Facility (ERF) computer system via a serial, asynchronous fiber optic data link. In addition, the latter signals are transmitted separately to a series of Light Emitting Diodes (LED's) contained in a Control Board display module to give continous indication to reactor operators regarding the water-covery status of each sensor. Also, available for auxiliary system use are analog output signals to indicate percentage water levels in the upper head and plenum regions and an associated Control Board annunciator alarm signal.

The HJTC system includes two identical probe assemblies (forming separate Trains A and B) located 180° apart and near the reactor core periphery, each in the proximity of the cold leg inlets, illustrated in Fig. 1. The HJTC probe assemblies are designed to be rugged structural members in the reactor vessel, such that their structural integrity is not threatened by transient conditions considered in the structural design of reactor vessel internals. Likewise, the probe assemblies are designed to cause negligible impact upon the thermal-hydraulic characteristics of the reactor system. Each probe is housed in a stainless steel structure which is designed to provide adequate probe support and to protect the probe sensors from damaging effects due to flow induced loads.

As indicated in Fig. 2, each probe assembly contains eight sensors functionally separated into two sections so that two sensors are located in the upper head region (above the Upper Support Plate), and six sensors are located in the upper plenum region (between the Upper Core Plate and the Upper Support Plate). This "split-probe" design was selected because of the limited hydraulic transport between the upper plenum and head regions. Thus, changes in coolant inventory within the two regions can be detected separately and independently.

This design also minimizes effects of differences in static pressure between the upper head and plenum regions which depend upon the status of Reactor Coolant Pump (RCP) operation. Due to the relatively small coolant flow in the upper head region of the reactor vessel, RCP operation will have no significant effect upon the two-phase response in this region. Therefore, the HJTC measurement in the upper head region is expected to be the same regardless of whether or not the RCP's are running.

In the upper plenum region, however, static pressure differences caused by the forced circulation due to RCP operation can reduce the capability of the separator tube to create a representative single-phase collapsed water level. With the RCP's running, the HJTC measurement in the upper plenum region may tend to underestimate the reactor coolant inventory since the static pressure in the upper portion of this region (just below the Upper Support Plate) is expected to be greater than that in the lower portion (just above the Upper Core Plate). Thus, operating procedures will require that the HJTC upper plenum measurements be disregarded until all RCP's are tripped during a small break LOCA.

The axial locations (relative to the heated thermocouple junctions) of the HJTC sensors within each probe assembly were selected to optimize the instrument capability to provide useful information to the operator regarding changes in reactor coolant inventory. The top sensor is located as high as practicable in the upper head region (approximately 49 in. above the vessel head mating surface). Uncovery of this sensor will provide the operator with early indication of the beginning of reduction of coolant inventory in the upper head region.

The second sensor in the upper head region is located just above (approximately 0.25 in.) the vessel head mating surface. This surface marks the top of the orifice holes around the periphery of the downcomer annulus which allows coolant transport between the upper head region and the core-inlet region in the lower plenum of the reactor vessel. Therefore, uncovery of the second sensor would effectively indicate loss of the complete coolant inventory in the upper head region available for reactor core cooling.

The remaining six sensors are located in the upper plenum region to provide more detailed information regarding changes in coolant inventory which have a direct effect upon core cooling. One sensor is located as high as practicable (approximately 4.5 in. below the Upper Support Plate). Uncovery of this sensor would provide early indication that the approach to ICC has begun due to loss of coolant inventory in the upper plenum region.

Three sensors are located axially proximate to the reactor vessel hot leg, at levels corresponding to the top, middle, and bottom (61, 47, and 33 in., respectively, above the Upper Core Plate). These sensors are intended to provide the operator with more detailed information during approach to ICC when the rate of loss in coolant inventory may change rapidly. Uncovery of the sensor proximate to the top of the hot leg would indicate the impending loss of natural reactor coolant circulation. Subsequent uncovery of the middle and bottom sensors in the hot leg region would indicate the approach of conditions in which no more coolant will drain from reactor coolant

piping into the vessel, after which the rate of approach to ICC may increase significantly.

To provide maximum continuity of information during the final stages of the approach to ICC, the lower two sensors in the upper plenum region are located at approximately equal axial intervals in the space between the bottom of the hot leg and the Upper Core Plate. The higher sensor is positioned 11 in. below the hot leg and 22 in. above the Upper Core Plate. The lower sensor is located as close as practicable to the top of the core (22 in. below the hot leg and 11 in. above the Upper Core Plate). Uncovery of this bottom sensor would indicate that the approach to ICC has proceeded to the point that core uncovery is imminent. Subsequent ICC monitoring prior to refilling of the upper plenum region must rely upon output signals from the CCM as discussed previously.

The HJTC probe design has undergone extensive tests performed by C-E to demonstrate its capability to perform its intended function. Proof of principle testing of the thermocouple sensor response is described in Ref. 2. This initial series of tests (Phase I) demonstrated the ability of the probe assembly to create and measure an effective collapsed water level in a two-phase mixture. A second series of tests (Phase II), described in Ref. 3, was performed to examine probe assembly behavior under fluid conditions similar to those anticipated to exist in a PWR during steady-state operations and during transients. These tests demonstrated that the probe assembly is capable of measuring coolant inventory in a reactor vessel. A final series of testing (Phase III) was performed to examine overall HJTC system response under simulated single-phase and two-phase fluid conditions representative of those to which the probe assembly might be exposed during a loss-of-coolant inventory event in a PWR vessel (Ref. 4). These tests verified capability of the HJTC system to measure and display coolant inventory above the reactor core, thus indicating the status and trend of inventory changes during an accident.

Further information regarding the design of the HJTC system and its application as part of an ICC monitoring system may be found in Refs. 5 and 6. Use of the HJTC system in Westinghouse designed reactors, such as CPSES, is described in Ref. 7. Specific applications of the design concepts, and necessary reactor vessel modifications, described in Ref. 7 have been performed at CPSES with cooperative interface support by C-E and W.

3.3 Instrumentation Displays and Alarms

As indicated in Fig. 4, the ICC monitoring system instrumentation includes three displays (for each separate train) located on the RCS portion of the Control Board to continuously provide the reactor operator with clear, easy-to-interpret visual indication of reactor core cooling conditions. These include CCM output analog meters to indicate the highest core exit temperature and the RCS saturation margin and a series of LED's located close by to indicate the condition (covered or uncovered) of each HJTC sensor. The design and location of these qualified, dedicated displays have undergone human-factors analysis as part of the CPSES Control Room design review performed in response to requirements of NUREG-0700. Use of these displays will not be inhibited by the actuation of other system alarms during an emergency.

In addition to the dedicated Control Board displays, the CCM and HJTC instrumentation systems include, or provide for, other supplementary types

of system information displays and system alarms. These various ICC monitoring system displays and alarms are described below.

3.3.1 Core Cooling Monitor System

The CCM microprocessor provides CET and SMM output temperature signals in engineering units which are indicated by the side-by-side meters illustrated in Fig. 6. Each meter covers the entire functional range of the corresponding instrument measurement. The CET measurement (left-side meter) provides the maximum valid core exit temperature on a scale of 0-2300°F (50 degree minimum scale interval). The SMM measurement (right-side meter) indicates the computed RCS saturation margin on a scale ranging from 300°F subcooled, to saturation (0°F), to 300°F superheated (10 degree minimum scale interval). During normal reactor operations, each CCM meter indicator can be expected to always remain in the bottom-half portion of the scale, giving redundant indication of adequate core cooling (i.e. CET readings significantly below the threshold for impending ICC and SMM readings well within the subcooling region). However, in the event of an accident causing an approach to ICC conditions, the SMM reading would rise to mid-scale (0°F indicating saturation) or above (indicating the margin away from saturation in the superheated region). Subsequently, the CET reading would also rise (at a slower rate). As discussed previously in Section 2.1, the threshold of impending ICC is considered to be a CET reading of 1200°F. Since the monitored CET reading represents the maximum measured core exit temperature, it can be expected that adequate core cooling would exist as long as the CET reading does not rise well into the top-half portion of the CET scale.

In addition to the CET and SMM analog meters, the CCM provides capability for other supplementary information displays. As indicated in Fig. 4 and discussed later, the CCM microprocessor transmits all input signal data, plus the computed saturation margin and the CCM instrument status, to the ERF computer. These data are sent in engineering units as a continual, digital data stream at one-second intervals. Use of these data by the ERF computer includes the capability to obtain on demand a readout of the CET temperatures as well as the computed saturation margin and the parameters used for its determination. Similarily, all input signal data are also transmitted to the Plant Process computer. This computer provides capability to obtain on demand a hard-copy, spatially-oriented core map which indicates the measured temperature at each CET location (see Fig. 1).

A further display capability is provided by the CCM, whereby a fully-isolated instrument service port can be used as an optional data-service connector. If desired, a standard RS-232 ASCII computer terminal can be attached to this port. The output data received include all CET measurements and are formatted and in engineering units, similar to those transmitted to the ERF computer. It can be seen in Fig. 1 that the CET measurements in each train include more than four thermocouples per core quadrant. Due to this display capability in addition to that provided by the ERF computer system (discussed further below), no backup display is included to provide selective reading of CET temperatures.

3.3.2 Heated Junction Thermocouple System

As indicated in Fig. 4, the HJTC microprocessor output includes a set of sensor signals which control a series of LED indicators on the Control Board. The LED's for both instrument trains are arranged in a display

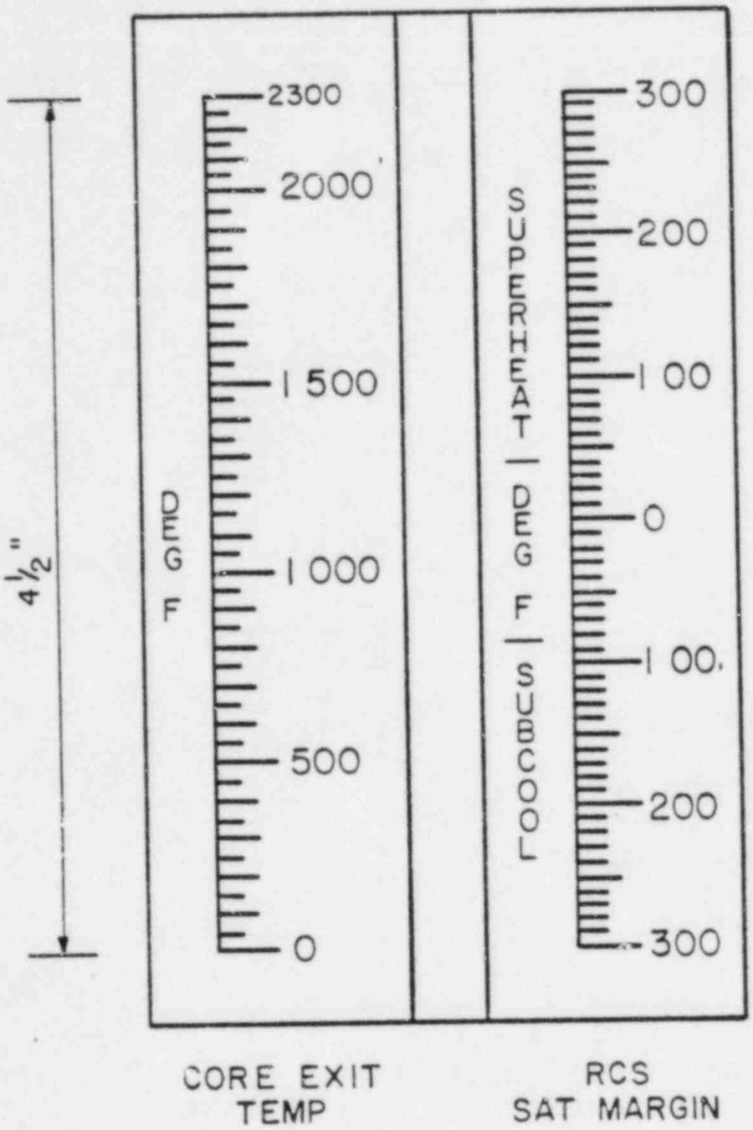

FIG. 6 CORE COOLING MONITOR SYSTEM TRAIN A CONTROL BOARD DISPLAYS (TRAIN B SIMILAR)

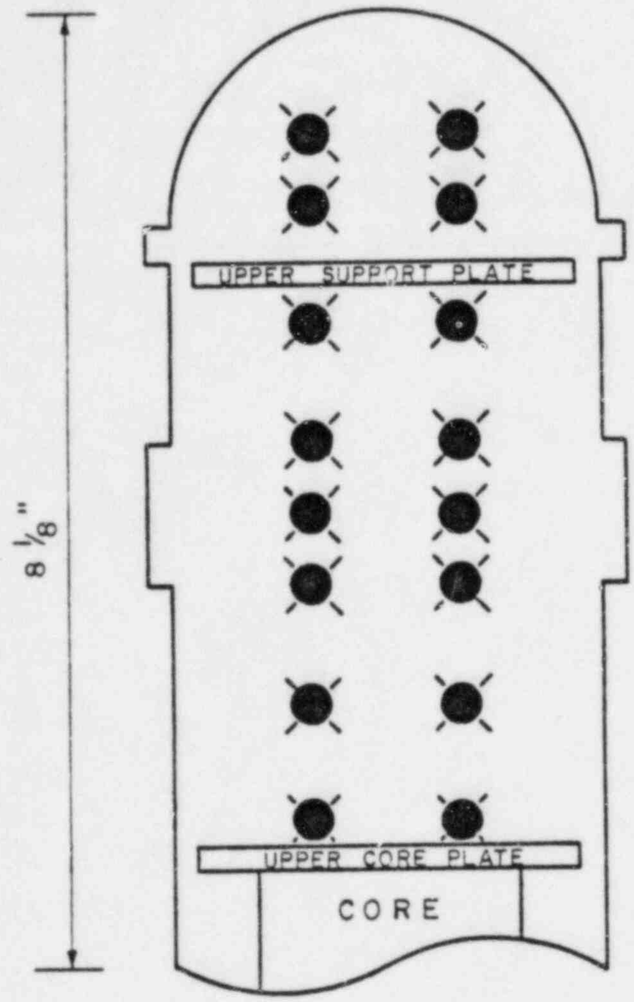

FIG. 7 HEATED JUNCTION THERMOCOUPLE SYSTEM CONTROL BOARD DISPLAY (TRAIN A & B)

module illustrated in Fig. 7. The system is designed such that the LED for each HJTC sensor is on (red shining light) as long as the sensor is covered (i.e., immersed in a water medium). An uncovered sensor (representative of a surrounding void or vapor medium) is indicated when the corresponding LED is off. As the LED's turn off during an approach to ICC conditions, the display module clearly indicates the progression of HJTC sensors becoming uncovered (i.e., the reduction in collapsed water level) in either of the upper head or plenum regions.

In addition to the Control Board display module, the HJTC system includes other supplementary displays. The system electronics cabinet located in the Control Room has transparent doors to allow visual observation of a digital readout module mounted on the microprocessor chassis. This module gives a demand readout of either computed percent coolant level or maximum coolant temperature.

3.3.3 System Failure Alarms

As indicated in Fig. 4, both the CCM and HJTC system microprocessors provide output alarms to inform the reactor operator that a system failure has occurred. Each of these system failure alarms may be triggered by any of several types of failures including a defective sensor, signal-transmission device or microprocessor component. Failure alarms are discussed further in Section 3.5.

Both system microprocessors include output capability to actuate annunciator alarms based on setpoint signal levels representing the measured variables. However, these alarm signals are not presently intended to be used, since the function of the ICC instrumentation will be to provide monitoring capability to the reactor operators.

3.4 Computer Functions

In response to requirements of NUREG-0696, CPSES is in the process of implementing an integrated, highly-reliable computer system as part of the Emergency Response Facility (ERF). This system is designed to provide greater than 99 percent availability during normal reactor operations and during plant cooldown. The ERF computer system will be used to provide plant-status information to the Control Room, Technical Support Center, and Emergency Operations Facility. The system hardware includes dual PRIME 750 computers, data acquisition system (DAS) equipment, an integrated Terminal Concentrator, and a number of high-resolution, human factor designed, color graphic display units. The DAS can process as many as 400 analog and 600 digital data signals.

Part of the incoming data to the ERF computer system will include the CCM and HJTC system microprocessor output data, as indicated in Fig. 4. The data transmitted from the CCM will include all CET measured temperatures, highest CET temperature, RCS pressure and pressurizer pressures, hot and cold leg RTD temperatures, computed saturation margin and CCM system status information. The data provided by the HJTC system will include all heated and unheated thermocouple temperatures, differential temperatures, sensor statuses, computed percent primary coolant level (inventory), highest thermocouple temperature and HJTC system status information. All incoming data are stored in a data base which can be accessed for display of selected values.

A portion of the ERF computer system software is identified as the Safety Parameter Display System (SPDS). This system is designed to provide variable output demand displays on the color graphic display screens to inform the reactor operator of the numerous operational parameters related to plant safety. Generally, the SPDS will indicate numeric values and bar-graph representations (updated at 1-second intervals) and time-dependent trend values (based on 30-minute operating trends with updates at 6-second intervals). The Core Cooling trend information display will include the highest CET temperature, computed lowest saturation margin and HJTC-indicated minimum percent water level. These data will also be available, along with the RCP operational statuses, in the ICC monitoring display which is part of the Accident Indication Detection System (AIDS) portion of the SPDS. This portion of the SPDS receives updates at 1-second intervals.

The Control Room includes three screens where SPDS displays may be viewed. Two color graphic display units are part of the Supervisor Console. A third "slave" CRT unit is located on the main Control Board very near to the dedicated ICC monitoring displays described previously.

The ERF computer hardware and associated DAS are installed and operational. Installation of the hardware equipment, including train isolation devices, connecting the CCM to the system is complete. Development of the associated software for processing CCM data is scheduled for completion by April 1984. HJTC system equipment components, and associated isolation devices, connecting to the ERF computer system have not been completely installed. The schedule for complete installation and implementation of the HJTC system is discussed in Section 5.0.

In addition to the newly-developed ERF computer system, the original Plant Process computer will also provide useful output in response to ICC instrumentation measurements. This unit is a W P2500 computing system with hard-copy printout hardware. All output signals from the CCM will also be transmitted to this computer. Part of the hard-copy printout from this system available on demand will include a spatially-oriented core map illustrating all CET temperature measurements and also corresponding temperature differences (i.e., average cold leg temperature subtracted from CET temperature).

3.5 Equipment Qualification

To the extent feasible, the CCM and HJTC systems to be used for ICC monitoring at CPSES will be qualified, Class 1E systems. The statuses of component qualification of these systems are described below.

3.5.1 Core Cooling Monitoring System

The CCM system components have been upgraded to be fully qualified for the design-basis post-accident environment, with one exception. This exception concerns only the thermocouple assemblies inside the reactor vessel. The CET sensors themselves are the original thermocouples provided by the reactor vendor (W). Although these original sensors are not fully qualified, considerable redundancy exists due to the total number of sensors and their spatial distribution. To upgrade the system to the extent feasible, the CET data transmission components (including all cables and connectors, junction boxes, and containment penetrations) leading from the reactor vessel to and including the dedicated Control Board displays have

been replaced with fully qualified equipment. The CET cables between the reactor vessel and the cold reference junction boxes have been replaced with fully qualified stainless-steel jacketed, mineral-insulated cable assemblies. The organic cable assemblies extending from the cold reference junction boxes to the control room microprocessors and displays are also fully qualified.

The CCM system consists of two fully redundant trains from the RCS sensors through the dedicated displays. The two trains are fully independent and are energized by separate Class 1E power sources. Physical separation, in accordance with Regulatory Guide 1.75, is maintained throughout the system with the necessary exception of the upper head region of the reactor vessel. Due to retrofit limitations and the need for representative distribution of each train of sensors into the areas of all four core exit quadrants, cables from both trains must share four vessel head penetrations (see Fig. 1). However, even within the passage through a head penetration, considerable separation exists due to the stainless-steel jacket of each separate mineral-insulated cable.

Above the reactor vessel, the CET cables are bundled into separate trains. Complete train separation is achieved at the missle shield and is maintained through the CCM microprocessor and to the dedicated Control Board displays. Qualified devices provide isolation in the data link between the CCM trains and the ERF computer.

The CCM system microprocessors are mounted in cabinets located in an area of the Control Room which is fully accessible for maintenance during normal operating and post-accident conditions. The cabinets and system electronics components are fully qualified for the Control Room environment and for conditions during and following a Safe Shutdown Earthquake (SSE). The system has been installed and is ready for operation during normal operating and post-accident conditions. No further qualification programs are planned for this system.

Multiple methods are available for checking the operational availability of each train of the CCM system. Various checking functions are automatically performed periodically by the microprocessors. A power failure or inability to activate a dead-man timer will trigger a system status alarm. All input signals are checked for validity by automatic comparison with extreme parametric range limits. Any sensor signals failing this test are flagged and excluded from possible use in the saturation margin computation. Although not represented by the dedicated Control Board displays, such failed data are retained and passed through the data stream to the ERF computer. The occurrence of such sensor failure also triggers an alarm. If for some reason the saturation margin computation can not be performed (e.g., in the unlikely event of failure of all required input sensor signals of a given category), a system failure alarm is triggered.

Due to the designed checking functions of the CCM system, the existence of fully redundant dual trains of the system, and the diverse distributions of multiple sensors within each train, no single failure within the system can render the entire system incapable of performing its intended function. Should a system failure lead to monitoring ambiguity or uncertainty regarding train availability, design test voltages simulating input sensor signals can be quickly accessed and applied, via a data/service port, to determine operability of each train. The microprocessor software includes a monitor program to permit full functional testing. With the designed interval testing capabilities and the use of a common computer terminal

(CRT), all processed signals can be monitored and reliable testing of the system can be performed to identify failed components and make necessary replacements or adjustments.

A defective channel can administratively be removed from service by either of two methods. The signal input wiring can simply be disconnected or, by connecting a CRT to the data/service port and using the internal monitoring program, selected signals may be deleted from the data scan.

3.5.2 Heated Junction Thermocouple System

The HJTC system being installed at CPSES will also be a seismically and environmentally qualified, Class 1E system. The system components procured from C-E are fully qualified according to the program described in Ref. 8. Presently, these components include the HJTC probe assemblies, the associated pressure-boundary equipment extending from the reactor vessel, and the system microprocessor and display equipment. The thermocouple sensor data transmission cable assemblies extending from the HJTC probe connectors (at the reactor vessel pressure boundary) to and including the containment penetrations are currently in the procurement stage. However, these components will also be fully qualified for the harsh post-accident environment. When system procurement and installation is complete, all associated components, from the HJTC sensors to and including the dedicated display module, will be fully qualified.

The HJTC system contains two identical and fully-redundant trains. As indicated in Figs. 1 and 2, the two identical probe assemblies, each containing eight sensors, are located 180 degrees apart near the reactor core periphery. Similar physical separation of the two trains is maintained from the probe assemblies to the separate microprocessors, and to the dedicated Control Board display. Qualified fiber-optic cables provide train isolation in the data link between the microprocessors and the ERF computer. These isolation devices are accessible for maintenance during normal operations and post-accident conditions.

The HJTC microprocessors are mounted in a two-bay cabinet located in an easily accessible area of the Control Room. Qualified separation in the cabinet is provided by a steel barrier between the two bays. Each train is powered by a fully independent and separate Class 1E power source. Electronic maintenance on the cabinet contents can be performed during normal operating or post-accident conditions. The cabinet and system electronics components are fully qualified for the Control Room environment and for seismic conditions during and following an SSE.

During operations, the HJTC system will undergo periodic tests and calibration. System maintenance procedures include a complete channel calibration cycle to be performed monthly. In addition to periodic system checks, the operator can assess operability by performing cross-channel checks in the event that an ambiguous indication should occur. Also, operational availability is automatically checked by the microprocessor itself. The electronics circuitry of the microprocessor employs a "flying capacitor" technique to obtain optimum isolation of the input signals. No single component failure will render the entire system inoperative. If a sensor thermocouple should fail causing an open circuit, a full-scale capacitor input voltage will result, and a fault condition will be detected

causing a failure alarm. Such a failure will be determined by an extreme differential temperature output (ΔT) and will cause the failed sensor to be excluded from future use.

If a sensor heater should break, an abnormally low ΔT fault condition will result and cause an alarm. Such a heater failure will exclude subsequent use of the sensor for indicating reactor coolant inventory, but the sensor will continue to measure local coolant temperature. A heater failure will, however, cause temporary loss of three additional sensors since the heater power circuits in each probe assembly feed groups of four heaters connected in series. Such a failure can be corrected at the microprocessor to restore use of the three non-defective heaters. Continuity checks can quickly identify the failed heater. The other three heaters can be easily restored to use by a simple change in wiring termination at the microprocessor. The end result of a single heater failure, which is unlikely to occur, is to lose the capability of one sensor in one channel to indicate sensor covery or uncovery.

3.5.3 Criteria and Standards

The ICC monitoring system equipment described above has been, or is being, procured, manufactured and installed in accordance with the quality assurance criteria and qualification standards listed below.

10CFR50 Appendix B, "Quality Assurance Criteria for Nuclear Power Power Plants and Fuel Processing Plants"

ANSI N45.2-1971, "Quality Assurance Program Requirements for Nuclear Facilities"

ANSI N45.2.9-1973, "Requirements for Collection, Storage, and Maintenance of Quality Assurance Records for Nuclear Power Plants"

ANSI N45.2.11-1973, "Quality Assurance Requirements for the Design of Nuclear Power Plants"

ANSI N45.2.13-1973, Quality Assurance Requirements for Control of Procurement of Items and Services for Nuclear Power Plants"

NUREG-0588, Rev. 1 "Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment"

IEEE Std. 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations"

IEEE Std. 344-1975, "IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations"

IEEE Std. 381-1977, "IEEE Standard Criteria for Type Tests of Class 1E Modules used in Nuclear Power Generating Stations"

IEEE Std. 383-1974, "IEEE Standard for Type Test of Class 1E Electrical Cables, Field Splices and Connections for Nuclear Power Generating Stations"

IEEE Std. 384-1977, "IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits"

4.0 SYSTEM APPLICATION

The CPSES emergency procedure, identified as FRC-0.1, "Response to Inadequate Core Cooling," is based on the HP-Basic version of the generic Westinghouse Owners Group Emergency Response Guideline (ERG), FR-C.1. The intent of this generic guideline is to provide systematic methods for restoring adequate core cooling and minimizing possible core damage in the event that ICC conditions should occur.

If ICC conditions are suspected, e.g., due to an indicated loss of subcooling (reduced saturation margin), the initial operator action is to attempt to provide high-head safety injection (SI). If this attempt is successful, the operator is instructed to return to the emergency procedure in effect when containment monitored conditions, CET temperature readings, and monitored secondary system conditions are normal.

If some source of high pressure water for SI cannot be made available, the operator is instructed to reduce primary system pressure by depressurizing the secondary system. Initially, this action will provide accumulator injection to accomplish core recovery and then allow the low-head SI to provide long term core cooling. If depressurization of the primary system cannot be accomplished in this manner and if CET temperatures exceed 1200°F, the operator is instructed to depressurize the RCS using all available RCS vent paths. When the steps to Procedure FRC-0.1 are successfully completed, the operator will then return to the ERG in effect to complete cooldown of the plant.

The generic ERG's assume the availability of RVLIS measurements, using the W system, in addition to CET temperatures, to indicate ICC conditions. As described previously, the HJTC system obtained from C-E is being installed at CPSES to perform the RVLIS function, i.e., to indicate reactor water level. Due to differences in principle, some revisions to the plant-specific emergency Procedure FRC-0.1 are required to implement the HJTC system for indicating the approach to ICC. These revisions will be defined and incorporated when the HJTC system is completely installed and made operational. Incorporation of these revisions will be accomplished in accordance with ODA-204, "Preparation of Emergency Response Guidelines."

As noted above, CET temperatures are employed by reactor operators to diagnose the existence of ICC and determine appropriate response actions. Although the CET measurements will continuously be recorded and displayed during all plant operations, they will will not be used regularly to affect operator actions during normal reactor operations.

The use of CET's has been integrated into reactor operator training associated with the following classroom topics:

1. CPSES Nuclear Systems, including the Incore Instrumentation System, Reactor Vessel and Internals, and Plant Computer

2. Procedure Review, including Emergency Procedures and Abnormal Procedures

3. Transient and Accident Analysis, including Natural Circulation

4. Mitigating Core Damage

In addition, the use of CET's has been incorporated into operator Control Room walkthroughs and simulator training. When the Emergency Operating Procedures are revised to incorporate use of the HJTC system for monitoring the approach to ICC, the operator training subjects listed above will also be revised accordingly. This training will be scheduled as appropriate in support of the HJTC system implementation.

The ICC equipment components, including the CCM and HJTC systems, have been designed to be capable of independent testing of instrument channels. During reactor operations after system implementation is complete, periodic testing of instrument channels will be performed. Development of the surveillance test procedures to perform these periodic tests will employ IEEE 338-1977 as a guideline.

5.0 SYSTEM IMPLEMENTATION

The CCM system, including the CET and SMM instrumentation, is installed and fully operational. The part of the ICC monitoring instrumentation not yet completely installed is the HJTC system.

The schedule for implementation of the HJTC system has been re-evaluated, and efforts are in progress to expedite installation of this system. The reactor vessel internal support structures for the HJTC probe assemblies have been installed in Unit 1. During initial reactor operations, plug gauges (dummy probes) will be used temporarily to occupy the spaces into which the actual probe assemblies will be installed later. These plug gauges are designed to provide pressure boundary seals identical to those given by the upper portions of the probe assemblies.

The principal portions of the HJTC system which are not yet available for installation are the necessary in-containment cable assemblies and the associated containment electrical penetrations. These items are in the procurement phase. The containment electrical penetrations are scheduled for delivery in the first quarter of 1984; however, delivery of the in-containment cable assemblies is not feasible prior to the fourth quarter of 1984. After delivery, installation of the cable assemblies, and the instrument probes, will require access to the reactor cavity and vessel head areas. Therefore, installation of the HJTC system in Unit 1 is scheduled to be completed during the first CPSES refueling outage, at which time the system will be made operational.

Prior to implementation during the first refueling outage, the CPSES Emergency Operating Procedures will be revised to incorporate use of the HJTC system. Corresponding training for reactor operators will be scheduled as appropriate and should have no effect upon the system implementation schedule.

6.0 SYSTEM DOCUMENTATION

The intent of this status report is to provide response to the documentation requirements of NUREG-0737 Item II.F.2, including the associated Attachment 1 and Appendix B. Table III provides a checklist to faciliate review of the submitted documentation to determine compliance with itemized requirements for the CPSES plant-specific ICC monitoring system. In Table III, the "reference" column identifies sections of this report, and/or appropriate listed references giving generic descriptions, which provide information pertinent to the corresponding response item. The column labeled "deviations" indicates whether or not the associated item for the CPSES system is known to be significantly different from the corresponding item for generically approved systems. Information provided in the column labeled "schedule" indicates either that documentation for the associated item is considered to be complete or the time (date or project developement event) when response to the item is expected to have been completed by an additional submittal. Generally, the items not noted as complete are considered to require further documentation contingent upon full implementation of the HJTC system.

TABLE III. DOCUMENTATION CHECKLIST FOR REVIEW OF CPSES ICC INSTRUMENTATION SYSTEM

ITEM	REFERENCE(S)	DEVIATIONS	SCHEDULE
NUREG-0737 II.F.2 DOCUMENTATION REQUIRED:			
1. a. Final design description of additional instrumentation and displays	Sec. 3.0 Refs. 2-7	No	Complete
b. Detailed description of existing instrumentation systems	Sec. 3.1	No	Complete
c. Description of completed or planned modifications	Secs. 3.1, 3.3-3.5	No	Complete
2. Design analysis and evaluation of water inventory monitoring instrumentation and test data to support Item 1 design	Secs. 3.2, 3.3 Refs. 2-6	No	Complete
3. Description of tests (planned or completed) for evaluation, qualification, and calibration of additional instrumentation	Secs. 3.3, 3.5 Refs. 2-6	No	Complete
4. Evaluation of conformance with NUREG-0737 II.F.2 Attachment 1 and Appendix B	Sec. 6.0 Ref. 6	No	Complete
5. Description of computer functions associated with ICC monitoring	Secs. 3.3, 3.4	No	Complete
6. Proposed schedule for installation, testing and calibration, and implementation of new instrumentation or information displays	Secs. 4.0, 5.0	No	Complete
7. Description of guidelines for use of ICC instrumentation and analyses used to develop these procedures	Sec. 4.0 Refs. 1, 5, 6	No	First Refueling
8. Summary of operator instructions in current emergency procedures for ICC and description of modifications when final ICC monitoring system is implemented	Sec. 4.0	No	First Refueling
9. Description and schedule for additional submittals needed in support of final ICC system and emergency procedures	Sec. 6.0	No	Complete

TABLE III. (Continued)

	ITEM	REFERENCE(S)	DEVIATIONS	SCHEDULE
	NUREG-0737 II.F.2 ATTACHMENT 1 CRITERIA (CET's):			
1.	Number and locations of CET's	Sec. 3.1	No	Complete
2.	a. Core map availability for indicating CET temperatures	Secs. 3.1, 3.3, 3.4	No	Complete
	b. Selective reading of CET temperatures	Secs. 3.1 3.3, 3.4	No	Complete
	c. Direct readout and hard-copy of CET temperatures	Secs. 3.1, 3.3, 3.4	No	Complete
	d. Availabilty of CET temperature time histories	Sec. 3.4	No	Complete
	e. CET alarm system	Sec. 3.3	No	Complete
	f. Human factor design of CET displays	Secs. 3.3, 3.4	No	Complete
3.	Backup display of CET temperatures	Secs. 3.3, 3.4	Yes	Complete
4.	a. Use of CET displays and alarms during normal and abnormal plant conditions	Secs. 3.3, 3.4, 4.0	No	Complete
	b. Integration of CET use into emergency procedures	Sec. 4.0	No	Complete
	c. Integration of CET use into operator training	Sec. 4.0	No	Complete
	d. Effect of other alarms on CET use	Sec. 3.3	No	Complete
5.	Conformance of CET instrumenation to NUREG-0737 Appendix B	Secs. 3.5, 6.0	No	Complete
6.	CET display channel power sources, independence and physical separation	Sec. 3.5	No	Complete
7.	Environmental Qualification of CET instrumentation	Secs. 3.1, 3.3-3.5	No	Complete
8.	Availabilty of CET display channels	Secs. 3.3-3.5	No	Complete
9.	Quality Assurance provisions of CET instrumentation	Sec. 3.5	No	Complete

TABLE III. (Continued)

	ITEM	REFERENCE(S)	DEVIATIONS	SCHEDULE
	NUREG-0737 APPENDIX B CRITERIA (ICC INSTRUMENTATION):			
1.	Environmental Qualification	Sec. 3.5	No	Complete
2.	Results of single component failure	Sec. 3.5	No	Complete
3.	Class 1E power sources	Sec. 3.5	No	Complete
4.	Availability prior to an accident	Sec. 3.5	No	Complete
5.	Quality assurance requirements	Sec. 3.5	No	Complete
6.	Continuous indication displays	Secs. 3.3,3.5	No	Complete
7.	Recording of instrumentation outputs	Sec. 3.4	No	Complete
8.	Identification of displays	Sec. 3.3	No	Complete
9.	Channel isolation devices	Secs. 3.4, 3.5	No	Complete
10.	Means for checking operational availability	Secs. 3.4, 3.5	No	Complete
11.	Servicing, testing, and calibration	Secs. 3.4, 3.5 4.0	No	First Refueling
12.	Channel removal from service	Sec. 3.5	No	Complete
13.	Administrative control of access to setpoint adjustments, calibration and test points	Sec. 3.5	No	Complete
14.	Minimization of anomalous indications	Secs. 3.3, 3.4	No	Complete
15.	Response to existence of malfunctioning components	Sec. 3.5	No	Complete
16.	Sensor direct measurements	Sec. 3.1	No	Complete
17.	Application during normal operations and accident conditions	Secs. 3.3-3.5 4.0	No	First Refueling
18.	Periodic testing of instrumentation channels	Sec. 4.0	Yes	First Refueling

7.0 CONCLUSION

Subject to completion of installation of the HJTC system and full implementation of this system in conjunction with the CCM system into the plant Emergency Operating Procedures, it is concluded that all ICC monitoring instrumentation requirements in response to NUREG-0737 Item II.F.2 will be fulfilled for CPSES. The combined ICC monitoring system, providing redundant measurements of RCS saturation margin, CET temperatures, and primary coolant inventory, will provide reactor operators with clear, easy-to-interpret indication of the approach to or existence of ICC conditions in a manner which is conducive to the maintenance or restoration of adequate core cooling so as to preclude or minimize reactor core damage in the event of a small break LOCA.

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