OAK RIDGE NATIONAL LABORATORY

OPERATED BY MARTIN MARIETTA ENERGY SYSTEMS, INC

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37831

May 9, 1988

Dr. Tai L. Huang
Reactor Systems Branch
MS WF1 8E23
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Huang:

Attached is our Trip Report of the post-implementation audit of the McGuire Nuclear Station Inadequate Core Cooling Instrumentation.

Sincerely,

John L. Anderson

John L. Anderson
Instrumentation and Controls
Division

JLA

Attachment

cc: E. W. Hagen
T. C. Morelock
File-NoRC

X003
1/1

TRIP REPORT

EVALUATION OF INADEQUATE CORE COOLING INSTRUMENTATION AT

McGUIRE NUCLEAR STATION, UNITS 1 AND 2

APRIL 28, 1988

PURPOSE

On April 28, 1988, a trip was made to the McGuire Nuclear Plant of Duke Power Company (DPC) to evaluate the installation, performance, and maintenance history of Inadequate Core Cooling Instrumentation (ICCI) installed in response to the NRC requirements of NUREG-0737 and Generic Letter 82-28. The visit team consisted of the NRC/McGuire Project Manager Mr. Darl Hood, the NRC/ICCI Technical Manager Dr. Tai Huang, and Oak Ridge National Laboratory (OR ".) Principal Investigators J. L. Anderson and E. W. Hagen.

The purpose of the visit was not to evaluate the Utilities conformance to the requirements of NUREG-0737, Item II.F.2, as this was done with previous reviews and audits. Rather, the purpose was to collect and evaluate information derived form experience of installation, calibration and operation at selected plants typical of the different types of ICCI systems installed. This information will be used to assist in the assessment of the effectiveness and impact of the implementation of the ICCI requirements. The McGuire visit was the first of several visits planned to obtain a cross-section of the several different types of systems that were installed by different utilities.

DESCRIPTION OF ICC INSTRUMENTATION SYSTEM

As required by NRC, the ICCI system at McGuire Units 1 and 2 consists of a Subcooling Margin Monitor (SMM), Reactor Vessel Level Instrumentation System (RVLIS), and Core Exit Thermocouples (CET). The system installation was approved by NRC and became operational in 1984.

Subcooling Margin Monitoring

The SMM system consists of two redundant trains of instrumentation with appropriate separation and independence and are separately powered from Class 1E power sources. Each train uses a digital processor with isolated inputs from reactor coolant system wide range pressure, reactor coolant system low range pressure, core exit thermocouples, and wide range reactor coolant hot leg RTD's. The primary display for SMM information is on a color-graphics cathode ray tube (CRT) display from an Operational Aids Computer (OAC). The CRT is located above control panel MC2 and the keyboard control is on the operators' desk MC15 (see attached sketch - Fig. 1). The OAC is not a qualified system, but provides coordinated integration of important plant information and includes the Safety Parameter Display System (SPDS). The redundant qualified backup displays for the SMM are Plasma Display Units (PDU) located on the vertical portion of control panel MC1. These programmable displays provide both graphical and numeric indication of subcooling margin and other pertinent parameters (Fig. 2).

Reactor Vessel Level Instrumentation System

The McGuire RVLIS is a generic Westinghouse design using two redundant trains of three differential pressure (dp) transmitters each. The "Upper Range" measures from the top of the vessel head to the bottom of the hot leg. The "Lower Range" measures from the bottom of the hot leg to the bottom of the vessel. The "Dynamic Head" sensor measures in the same location as the Lower Range, but is scaled to indicate the dp created by the dynamic head of the primary coolant pumps. The Dynamic Head indication will respond to increasing void fraction when the primary coolant pumps are running. The Upper and Lower Range indications provide more accurate level indication in their respective regions when the coolant pumps are not running, but are normally off-scale with the pumps in operation. The Westinghouse system uses sealed sense lines and hydraulic isolators (bellows) to minimize the quantity of primary system water in the lines. The temperature of the vertical runs of sense lines inside containment are measured with RTD's to provide compensation signals for changes in containment environment. The dp transmitters are located outside containment. Two types of electronic processing equipment are available for the Westinghouse systems. McGuire originally installed the analog signal processing version identified as the "7300" system. Later, in 1986, they replaced the analog system with digital microprocessor electronics. This was partly to benefit from the improved accuracy and stability of the microprocessor system and partly so that all of the DPC systems (McGuire, Catawba and Oconee) would be alike to minimize maintenance and training problems. The two redundant trains of RVLIS are independent and separately powered from Class 1E sources. The primary display is via the Operational Aids Computer and the qualified backup displays are the same PDUs described above for the SMM systems. Two of the RVLIS display screens are shown in Figs. 3 and 4.

Core Exit Thermocouple system

Each McGuire unit has 65 CETs. 40 of these have been upgraded and qualified and are divided into two trains of 20 each. Separate thermocouple containment penetrations are used for the two trains and separation is maintained to the processing cabinets in an equipment room near the control room. Signal processing and cold junction compensation is accomplished in these cabinets in a controlled environment. The 25 unqualified CETs have cold junction compensation inside containment and feed directly to the OAC. Isolated outputs from the qualified trains also feed the OAC where core maps and other primary displays are generated. The qualified backup displays for the qualified CETs are the PDUs also used for the SMM and RVLIS. The layout of the CET system is shown in Fig. 5. Selected CET outputs also are used in the SMM system.

INSTALLATION AND MAINTENANCE EXPERIENCE

RVLIS

The impressions given by the engineering staff involved are that the RVLIS system is now an accurate and reliable system. Some infant mortality was experienced with components and a few chronic problems with components, design, and installation techniques required early attention. They feel that these problems are now resolved and maintenance is routine.

Several early failures were experienced with the dp transmitters and hydraulic isolators. Both are manufactured by Barton and one DPC engineer expressed the opinion that perhaps the Barton quality control was not adequate. The failures were due to improper internal clearances and internal electrical short circuits.

Another chronic problem was the filling procedures and maintaining leak tightness of the sealed capillary system. Apparently, it is very difficult to maintain the capillary system leak-tight over a long period. Very small pinhole leaks or minute leaks through valve seals cause trouble in times shorter than a refueling cycle. The hydraulic isolators have position indicators on the bellows. These positions are monitored routinely and if the system leaks, early warning is provided before the system becomes inoperable. The capillary system can be back-filled on-line to restore the original isolator bellows positions. One source of slow leaks is the fill valves. A procedure was developed to cap and weld the fill lines after the system is filled to prevent leaks through the fill valves. Evacuating and refilling the sealed system is an expensive and time consuming operation. The Westinghouse field charge for this service is over $50,000. DPC has purchased equipment and has developed their own capability for this operation. Since initial installation, the McGuire sealed capillary systems have required refilling four times (about once per year). DPC and Westinghouse are investigating the feasibility of a design modification to eliminate the sealed capillary system because of its high maintenance cost.

When the analog signal processing system was in use, DPC found that the circuitry experienced considerable drift and that frequent recalibration was necessary. Although this was a relatively easy calibration process, it was time consuming and therefore expensive. When new RVLIS systems were purchased for other DPC plants the microprocessor systems were specified because of this experience with the analog systems. In addition, DPC opted to purchase a replacement microprocessor-based signal processing system for the McGuire units that is essentially the same as the other units (Catawba, Oconee). DPC purchased ICCI systems for all 7 of their units at one time. Maintenance experience with the digital systems has been much better than with the analog systems.

CET

The new head connectors and mineral-insulated cable for the qualification upgrade of the CETs creates new handling problems during refueling operations. The bulky connectors at the head ports require special care and handling because of tight fits through the access sleeves, and special waterproofing is needed when disconnected. Although the handling time during refueling is somewhat increased, no performance problems have been identified with the qualified CET installations. The remaining unqualified CETs are more susceptible to mishandling because they do not have elaborate seals, and some have been damaged.

When the new signal processing cabinets (also including RVLIS and SMM) were installed, a few early problems were experienced. Field connections were made to screw terminals on printed circuit cards which also have card edge connectors. Screw force applied in making field connections sometimes misaligned the card edge-connector pins and caused failures and mis-operation. The field connection cards were replaced with an upgraded design which eliminated this problem. In addition to the connector problems, some infant mortality of parts was experienced, but improved replacements have apparently solved this problem as well. DPC has been somewhat unhappy about the repair costs for circuit cards and other components from the manufacturer. DPC has developed their own diagnostic and repair capability, but was frustrated in this effort by deficiencies in documentation for the instrumentation and particularly for the software. Apparently Westinghouse guards the propriety of the designs carefully and regards DPC as a competitor for engineering services.

Initial software problems were apparently due to quality control deficiencies. Some of the problems included incorrect designations or locations on data displays and core maps, improper coefficients in compensation algorithms for impulse line temperature and system density (data confused with another plant), and incorrect functioning of failure auctioneering algorithms. These problems were readily identified during initial checkout and calibration and have been corrected by appropriate software upgrades (ROM chips). After initial debugging, DPC is pleased with the signal processing system performance. The system includes a software self-calibration routine that works well and effectively eliminates the problems experienced earlier with the analog system. Under normal conditions, McGuire attempts to maintain overall accuracy of 1.5% in the signal processing system. A complete system checkout and calibration after refueling requires two weeks per train. DPC was not satisfied with all of the displays provided with the system and has customized the displays to their own satisfaction through software modifications. The displays shown in Figs. 1-5, although similar to the original Westinghouse displays, are unique to McGuire.

SMM

The SMM system uses much of the same processing equipment as the RVLIS and CET systems and has experienced no special problems except as described for the other functions.

PERFORMANCE, TECHNICAL SPECIFICATIONS, PROCEDURES AND TRAINING

The CET and SMM portions of the system are used routinely and perform well. Since RVLIS is a post accident monitoring system and gives no useful information in normal operation, its acceptance is less well defined. It was indicated that the RVLIS is very useful during drain and fill operations and is usually kept operational until the sense lines are removed for refueling. Comparison with manometer indications during draining shows agreement within a few inches and operators have developed confidence in the indications. All operators are trained in the use of ICCI and ICCI indications are incorporated into operating and emergency procedures. The current McGuire training simulator does not have ICCI installed as a new simulator is on order and will be installed soon. The new simulator will have the full complement of ICC instrumentation as does the simulator at the Catawba plant.

It was pointed out that the ICCI systems are not referred to explicitly in the procedures and status trees, but the information displayed by the systems is referred to and used in many procedures and status trees. A number of examples were illustrated. It was noted on a typical status tree that reference was made to a particular vessel water level, but no branch or specific reference to pump status was indicated. However, the specific procedures reference by the tree include checks of pump status in relation to level information.

A visit to the control room revealed that the primary and secondary displays are well located for operator access and visibility. The secondary display panels are appropriately close to the primary pump controls and indications. Each backup display is multi-purpose being used for all three functions, SMM, CET, and RVLIS. The redundant displays are side-by-side and in normal operation the practice is to leave one display paged to SMM information and the other to CET information. Additional information is available on the color-CRT display of the OAC. A software problem persists in the RVLIS which causes a malfunction annunciator occasionally in response to the self-checking routine. The problem has been identified and will be corrected soon with a revised ROM chip.

Our overall impressions are that the systems are performing satisfactorily and that maintenance problems have been reduced to an acceptable level by gradual modifications. Operator acceptance is good and confidence in the indications is high.

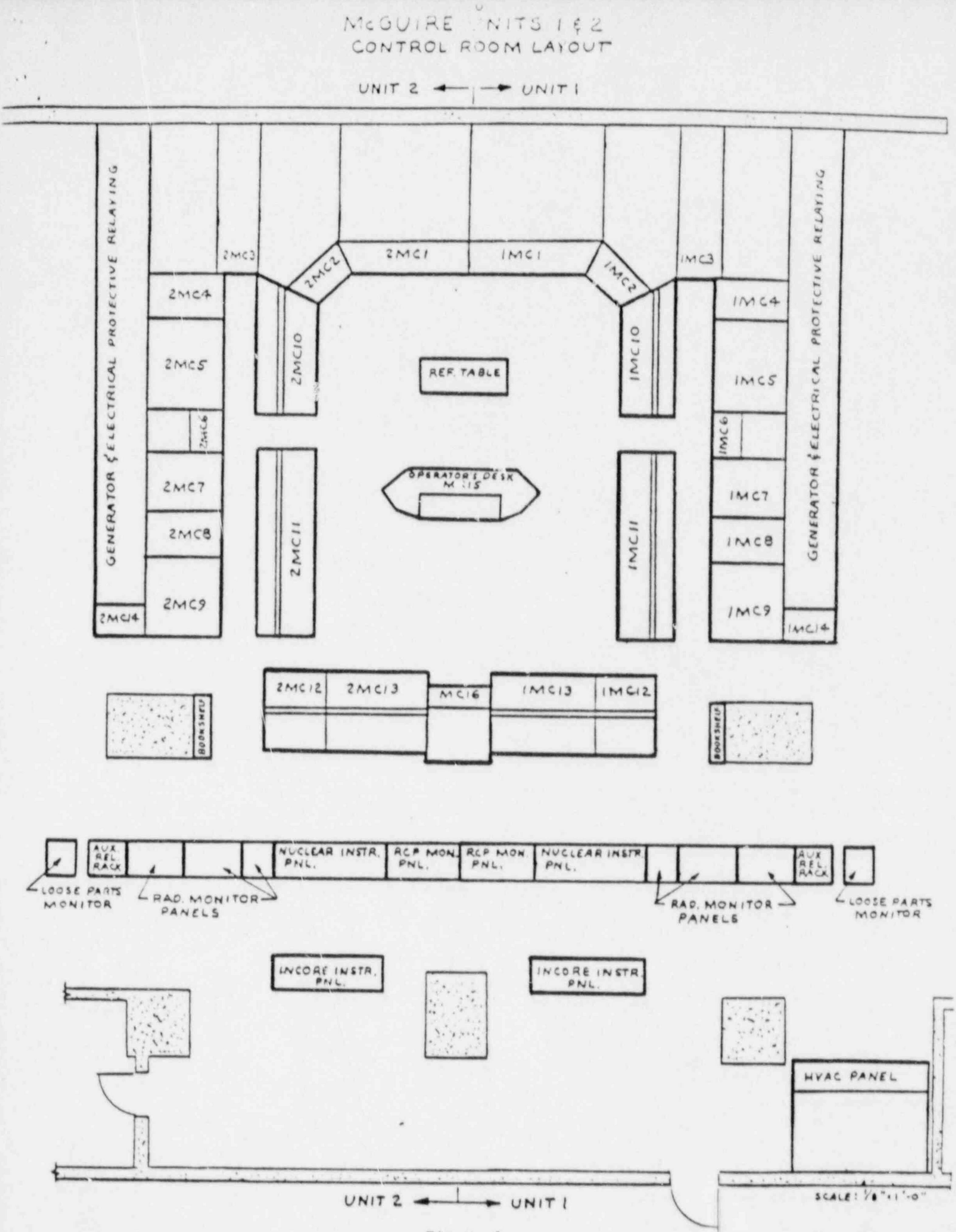

McGUIRE UNITS 1 & 2
CONTROL ROOM LAYOUT
UNIT 2
UNIT 1
GENERATOR & ELECTRICAL PROTECTIVE RELAYING
2MC3
2MC2
2MC1
1MC1
1MC2
1MC3
2MC4
2MC5
2MC6
2MC7
2MC8
2MC9
2MC14
2MC10
2MC11
REF. TABLE
OPERATOR'S DESK
1MC10
1MC11
1MC4
1MC5
1MC6
1MC7
1MC8
1MC9
1MC14
2MC12
2MC13
MC16
1MC13
1MC12
BOOKSHELF
AUX REL. RACK
NUCLEAR INSTR. PNL.
RCP MON. PNL.
LOOSE PARTS MONITOR
RAD. MONITOR PANELS
INCORE INSTR. PNL.
HVAC PANEL
SCALE: 1/8"=1'-0"

Figure 1.

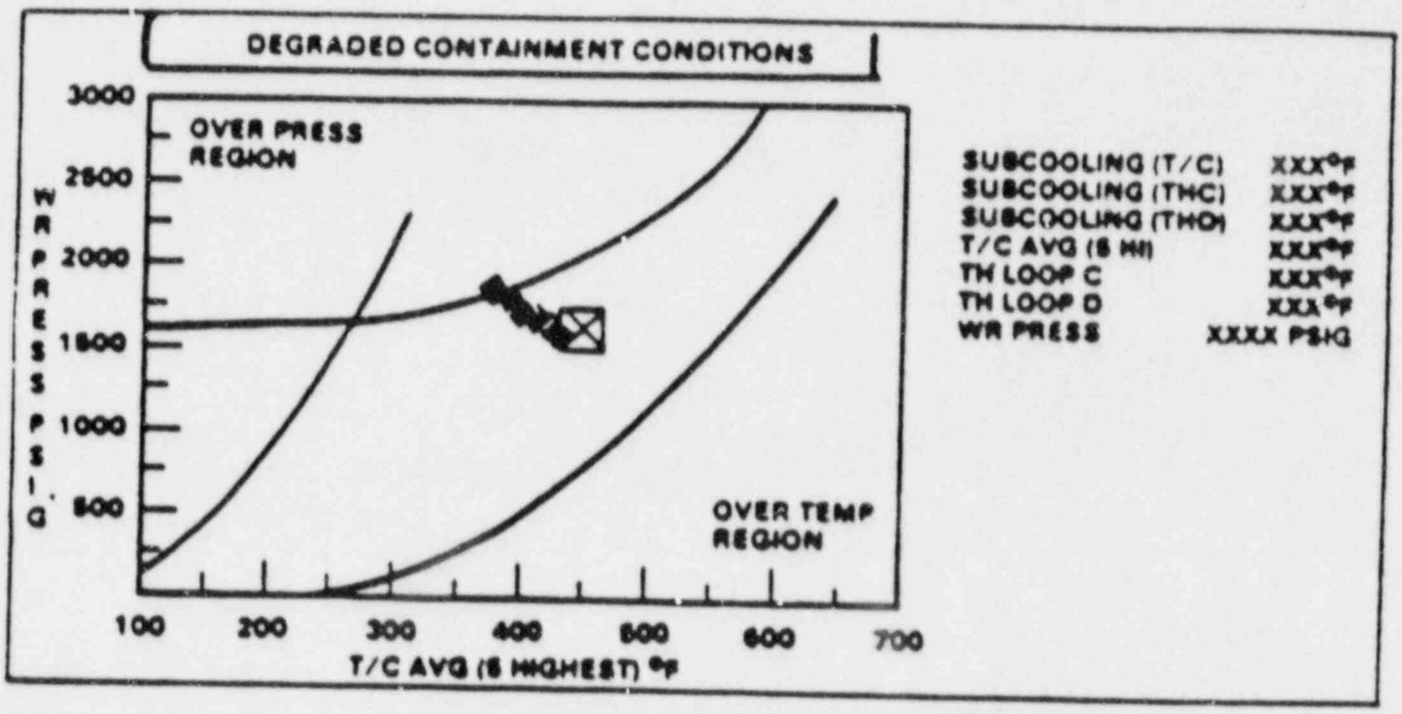

DEGRADED CONTAINMENT CONDITIONS
OVER PRESS REGION
OVER TEMP REGION
WR PRESS PSIG
3000
2500
2000
1500
1000
500
100
200
300
400
500
600
700
T/C AVG (5 HIGHEST) °F
SUBCOOLING (T/C) XXX°F
SUBCOOLING (THC) XXX°F
SUBCOOLING (THO) XXX°F
T/C AVG (5 HI) XXX°F
TH LOOP C XXX°F
TH LOOP D XXX°F
WR PRESS XXXX PSIG

Figure 2.

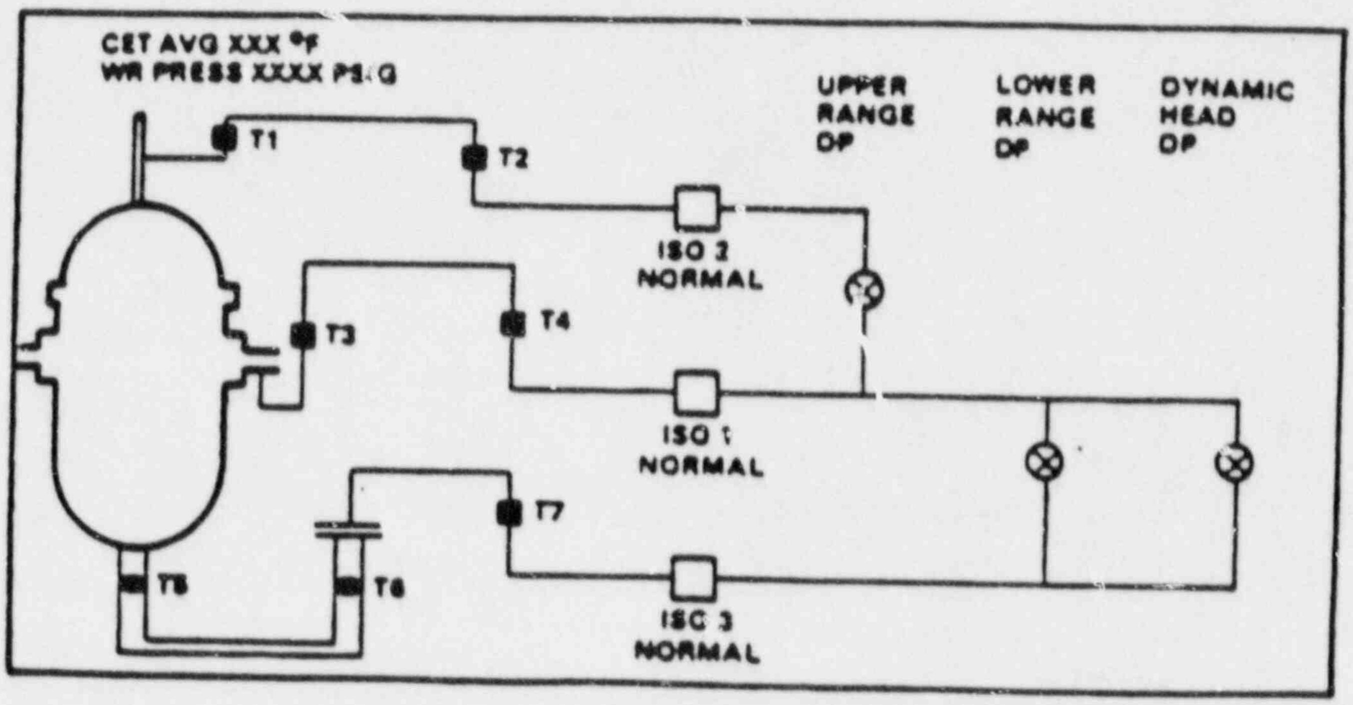

CET AVG XXX °F
WR PRESS XXXX PSIG
UPPER RANGE DP
LOWER RANGE DP
DYNAMIC HEAD DP
T1
T2
T3
T4
T5
T6
T7
ISO 2 NORMAL
ISO 1 NORMAL
ISO 3 NORMAL

Figure 3.

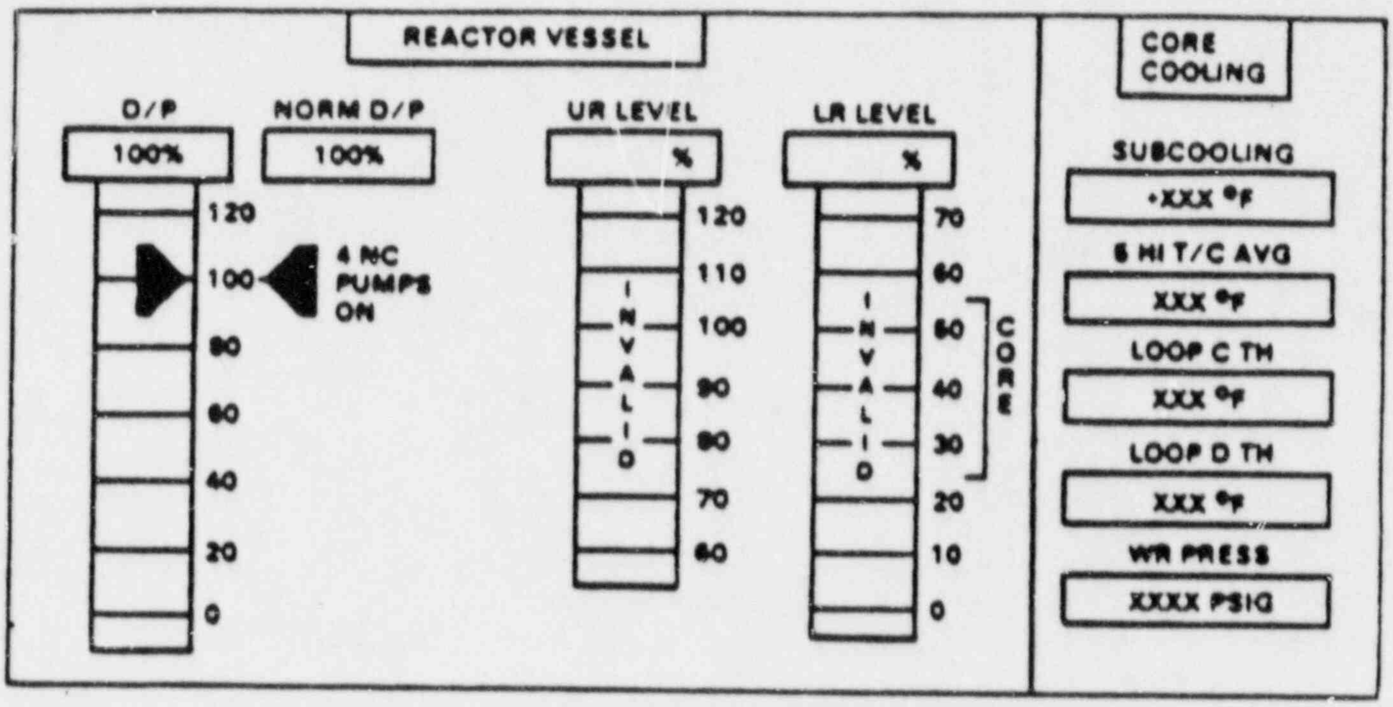
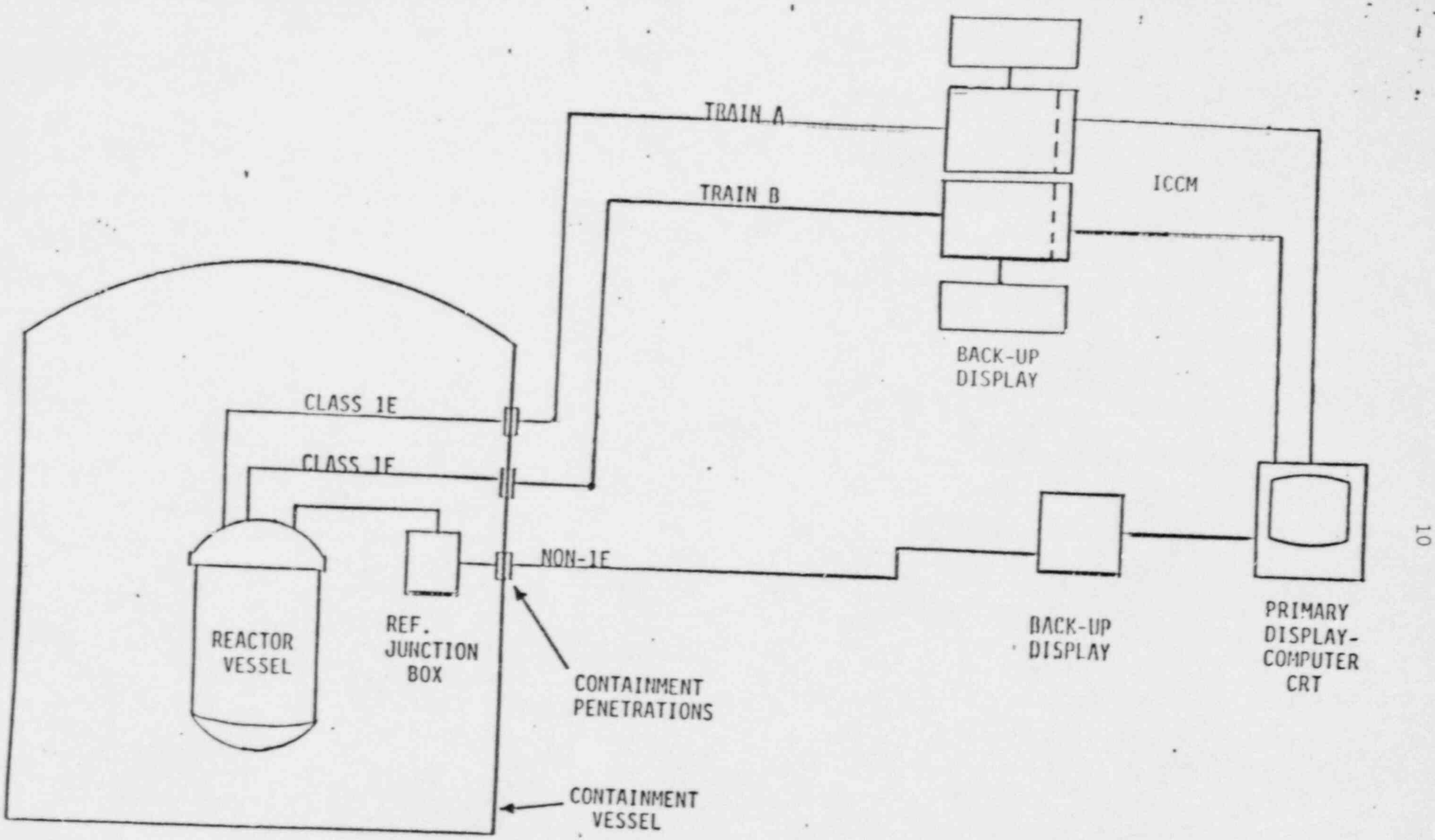

REACTOR VESSEL
D/P
100%
NORM D/P
100%
UR LEVEL
%
LR LEVEL
%
120
100
80
60
40
20
0
4 NC
PUMPS
ON
INVALID
120
110
100
90
80
70
60
70
60
50
40
30
20
10
0
CORE
CORE
COOLING
SUBCOOLING
+XXX °F
5 HI T/C AVG
XXX °F
LOOP C TH
XXX °F
LOOP D TH
XXX °F
WR PRESS
XXXX PSIG

Figure 4.



INCORE THERMOCOUPLES

Figure 5.