ARKANSAS NUCLEAR ONE - UNIT 1

INADEQUATE CORE COOLING (ICC)

MONITORING SYSTEM

FINAL DESIGN DESCRIPTION

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ANO-1 INADEQUATE CORE COOLING MONITORING SYSTEM FINAL DESIGN DESCRIPTION

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ANO-1 INADEQUATE CORE COOLING MONITORING SYSTEM
FINAL DESIGN DESCRIPTION

1.0 INTRODUCTION

1.1 Acronyms

1.1.1 - ICC - Inadequate Core Cooling
1.1.2 - RGT - Radcal Gamma Thermometer
1.1.3 - RLI - Radcal Level Instrument
1.1.4 - ICCMDS - Inadequate Core Cooling Monitoring and Display System
1.1.5 - AP&L - Arkansas Power and Light
1.1.6 - DTC - Differential Thermocouple
1.1.7 - CET - Core Exit Thermocouple
1.1.8 - ATC - Absolute Thermocouple
1.1.9 - LOCA - Loss of Coolant Accident
1.1.10 - RCP - Reactor Coolant Pump
1.1.11 - SPDS - Safety Parameter Display System
1.1.12 - FDU - Flourescent Display Unit
1.1.13 - EEPROM - Electrically Erasable Programmable Read Only Memory
1.1.14 - TEC - Technology for Energy Corporation
1.1.15 - B&W - Babcock and Wilcox

1.2 Overview of the Inadequate Core Cooling (ICC) Monitoring System

1.2.1 System Purpose

In the Arkansas Nuclear One, Unit 1 (ANO-1) installation, the inadequate core cooling monitoring and display system (ICCMDS) is designed to detect void formation in the reactor vessel dome and upper plenum region, and to track reactor coolant inventory in accordance with NRC requirements.

1.2.2 ICC Monitoring System Components

The RGT - ICC Monitoring System is based on a set of redundant Radcal Level Instruments (RLIs) which contain RGT sensors located at selected intervals within the instruments. The RLI design is based on proven technology nearly identical to that used for local power measurements in several European reactors. Each RLI consists of a cable pack of sheathed, single-difference thermocouples (one for each sensor), one absolute thermocouple, and a heater cable. Also there is an annular core rod which contains the cable pack and a jacket tube that surrounds the core rod/cable pack assembly. The RLIs traverse the entire region to be monitored and are to be inserted through the vessel head in the place of the center control rod assembly which is to be removed during the ANO-1 seventh refueling outage (1R7). RLIs are surrounded by manometer tubes and an overall tube within the existing control rod assembly guide tube. The manometer tubes are used to hydraulically isolate the coolant adjacent to the RLIs, thereby enabling the

RGTs to sense collapsed liquid level. Hydraulic isolation for dome versus plenum monitoring is to be accomplished by insertion of hydraulic isolators in the manometer tubes. The four (4) differential thermocouples (DTCs) located in the dome region can be read when the reactor coolant pumps are running.

In addition to the RLIs which provide above core level monitoring, core exit thermocouples (CETs) are part of the ICC Monitoring System and are located in the upper portion of the in-core neutron detectors. During the 1R7 outage, sixteen (16) qualified CETs will be installed and will provide a display on the Safety Parameter Display System (SPDS). Additional details regarding modification to CETs are provided in section 4.1.2.

Subcooling margin and superheat temperature calculation is also part of the ICC Monitoring System. This information is based on CET average temperature, reactor coolant system pressure, and saturation data contained in steam tables. The subcooling margin monitoring function provided by the ICCMDS is in addition to an already existing qualified subcooling margin monitoring system.

As part of the ICC Monitoring System, one (1) wide range and four (4) narrow range transmitters are utilized to monitor each hotleg water level. Locations of the various transmitters and the function of each is described in section 4.1.4.

The Inadequate Core Cooling Monitoring and Display System (ICCMDS) consists of two (2) Class 1E functionally and physically independent processing and display cabinets, and one (1) dual channel remote Mimic Display Panel. The display panel has been designed to accomodate two (2) instrumentation display channels. Each of the cabinets contains all necessary hardware and software required for proper system operation including microprocessor, data communications, multibus, input/output and real time data acquisition, fluorescent display unit (FDU), and other support electronics and miscellaneous hardware. Section 4.1.5 provides further details regarding the ICCMDS.

1.2.3 ICC Monitoring System Functions

The purpose of the ICC Monitoring System is to provide control room operators with an integrated and unambiguous indication which provides:

- advance warning and annunciation of approach to ICC,
- tracking of coolant inventory during an ICC event,
- tracking of coolant inventory during accident recovery, and
- coolant temperature measurements at core exit.

In addition to the above functions, the ICC Monitoring System provides for:

- RCS level indication under the following conditions
    - during normal decay heat removal
    - during fill and vent and drain operations
    - during RCS maintenance

- Calculation of subcooling margin based upon CET inputs

- Indication of reactor vessel head fluid temperature and level to aid during natural circulation cooldown operation

- Alarm for low decay heat suction level

In order to accomplish this, the ICC Monitoring System is required to monitor a variety of temperatures and pressures from various sensors within the reactor vessel and hotlegs to provide input to calculations performed by system software. The following variables are monitored;

- Reactor vessel level - The input parameters consist of a series of heated differential thermocouples contained within sensor rods installed in the reactor vessel.

- Hotleg water level - This is accomplished by monitoring ΔP from one (1) wide range and four (4) narrow range transmitters per hotleg. In addition, reference leg temperature inputs and CET average temperature are used for density compensation of the level.

- Core exit temperature - CETs are monitored within the reactor vessel in order to display temperature at the core exit.

- Subcooling margin and superheat temperature - This is calculated based on a CET temperature average, reactor coolant system pressure, and saturation data developed from steam tables.

In addition, reactor vessel head water temperature is input from an absolute thermocouple located at the uppermost portion of the RLIs.

2.0 BACKGROUND

2.1 NUREG-0737 Requirements

Following the March 1979 accident at Three Mile Island, the Nuclear Regulatory Commission (NRC) identified the need for additional instrumentation to detect inadequate core cooling. All power reactor licensees were required, by Orders issued in October 1979, to review and upgrade existing instrumentation. These Orders were to assure that information regarding the reactor coolant subcooling margin and core exit temperature over an elevated temperature range (detected by core exit thermocouples) is available to operators in the control room.

The NRC also proposed that the possible need for additional instrumentation be studied to provide an unambiguous, easy-to-interpret indication of ICC, and that such instrumentation be provided, if it is found to be necessary. Design requirements and qualification criteria for additional instrumentation are specified in NUREG-0737, Clarification of TMI Action Plan Requirements. On October 21, 1980 power reactor licensees were required, pursuant to 10 CFR 50.54(f), to provide a report detailing their planned instrumentation system for monitoring ICC conditions.

Following analysis of the information provided by the licensees, meetings with industry groups, and independent studies by the NRC staff, the Commission determined that during a small-break loss of coolant accident (LOCA), there is a period of time before the core has boiled dry (as indicated by core exit thermocouples); during which, control room operators would have insufficient information to clearly identify void formation in the reactor vessel head or to track coolant inventory in the vessel and primary system. Although the subcooling margin monitor gives early indication of a problem, it does not indicate whether the condition is improving or deteriorating.

The Commission concluded that the addition of a reactor coolant inventory tracking system would improve the ability of plant operators to diagnose an approach to inadequate core cooling and to assess the adequacy of actions taken to restore core cooling. The benefit would be preventive in nature; the instrumentation would help operators to avoid a degraded or melted core in the event that voids and saturation conditions in the reactor coolant system occur as a result of insufficient cooling events or accident conditions.

In addition, the Commission concluded that the addition of a reactor coolant inventory system, coupled with upgraded in-core thermocouple instruments and a subcooling margin monitor would constitute an ICC instrumentation package that could significantly reduce the probability of incorrect operator diagnosis and resultant actions. It would be effective for events such as steam generator tube ruptures, loss of instrument bus, control system upsets, pump seal failures, or overcooling events originating from disturbances in the secondary coolant system. For low probability events involving coincidental multiple faults or more rapidly developing small-break LOCA conditions, the ICC instrumentation could also reduce the probability of incorrect operator diagnosis and resultant errors that could lead to a degraded core condition.

2.2 License Modification

Subsequent to the foregoing studies, the Commission determined that an instrumentation system for detection of ICC is required for operation of pressurized water reactors. Therefore, by Order for Modification of License dated December 10, 1982, (OCNA128211), Arkansas Power & Light Company (AP&L) was required to "...install an ICC instrumentation system consisting of subcooling margin monitors, core exit thermocouples and a reactor coolant inventory tracking system, all of which conform to the design parameters specified in NUREG-0737, Item II.F.2."

2.3 Implementation Activities

In response to the Order for Modification of License, AP&L developed a system conceptual approach to meet the NUREG-0737, Item II.F.2 design parameters and subsequently presented their approach to the NRC staff on March 31, 1983. Based on a favorable response, AP&L complied with Sections III.2 and III.3 of the Order on April 15, 1983, by providing detailed schedules for engineering, procurement, and installation of the inventory tracking system, and provided an Item II.F.2 conformance report for all components of the ICC instrumentation system (1CAN048308). In addition, each of eight questions posed by the NRC on April 6, 1983 regarding the proposed system were answered in AP&L letter dated May 4, 1983 (0CAN058301).

The NRC documented, by letter dated August 5, 1983 (1CNA088301), that the proposed ANO-1 system provided a satisfactory basis for AP&L to proceed with the final design engineering and development program. This letter included additional questions regarding the monitoring system and implementation schedule.

After submittal of a Program Plan for ICC Systems on August 26, 1983 (0CAN088319), AP&L provided a response to some of the NRC concerns and a schedule for responding to those remaining in letter dated September 8, 1983. In letter dated January 13, 1984 (1CAN018404), AP&L provided responses to the remaining questions contained in NRC's August 5, 1983 letter and provided a revised milestone schedule for implementation of the necessary modifications. Additional details regarding the adequacy of the CET system were provided in AP&L letter dated March 7, 1984 (1CAN038401). This was in direct response to NRC letters of August 5, 1983 and February 14, 1984 (1CNA028402).

NRC letter dated May 7, 1984 (1CNA058402) addressed additional concerns regarding use of emergency operating procedures after a seismic event or cold junction thermocouple temperature accuracy during a transient event. AP&L letter dated June 11, 1984 (1CAN068405) responded to these concerns.

In AP&L letter dated March 18, 1986 (1CAN038604) changes to the ANO-1 ICC Program Plan were submitted in addition to a revised milestone schedule for completion of ICC monitoring system modifications. These changes involved the following:

- the use of a ΔP measurement system for tracking hotleg water level instead of the earlier proposed Radcal Gamma Thermometer (RGT) stillwell design and
- the use of qualified Core Exit Thermocouples (CET) for in-core monitoring instead of the earlier proposed RGTs.

2.4 Schedule for Completion of ICC Monitoring System Modifications

3.0 DESIGN REQUIREMENTS

3.1 Functional Requirements

The functional requirements of the ANO-1 ICC Monitoring System are to:

- Satisfy the NRC requirements given in NUREG-0737, Item II.F.2 for ICC monitoring. This is accomplished through the measurement of reactor coolant inventory above the core, and in the hotleg and
- Satisfy the NRC Order for Modification of License, dated December 10, 1982, to install an ICC Monitoring System for detecting and monitoring ICC conditions.

3.2 Operational Requirements

The operational requirements of the ANO-1 ICC Monitoring System are to:

- Provide capability for measurement of coolant inventory above the core,
- Provide processing of signals from existing core exit thermocouples,
- Provide capability for data transmission to AP&L's Emergency Facility Computer (i.e., Safety Parameter Display System),
- Provide capability for measurement of subcooled margin, and
- Provide processing of signals from hotleg level sensors.

3.3 Separation Requirements

The redundant, identical sensors and instruments of the ICC Monitoring System are physically and electrically separated in accordance with the requirements of NUREG-0737 and other qualification documents.

3.4 Environmental Requirements

3.4.1 Control Room Environment

The control room portion of the ICC Monitoring and Display System is designed to operate in the following environmental conditions:

	Normal	Accident Conditions
Temperature, F	75	60-105
Pressure, psia	14.7	14.7
Relative Humidity (noncondensing) percent	50-90	50-90
Radiation (TID)	1000 Rads	1000 Rads

3.4.2 Reactor Containment Environment

The containment portion of the ICC Monitoring System is designed to operate in the following environmental conditions:

	Normal	Accident Conditions
Temperature, F	120*	280
Pressure, psia	14.7	67.8
Relative Humidity, percent	90	100
Radiation Integrated Dose, R	10^7	$5x10^7$
Chemical Spray		
pH	na	10.5
Boric Acid, ppm	na	15,000
Sodium Hydroxide, ppm	na	As needed pH = 10.5

*The ambient temperature for components located near the reactor head was determined to be 170°F. These components were designed to operate under these conditions.

3.4.3 Reactor Internal Environment

The in-reactor portion of the ICC Monitoring System is designed to operate in the following environmental conditions:

	Normal	Accident Conditions
Temperature, F	670	2300
Pressure, psia	2500	2500
Relative Humidity	100	100
Gamma Flux (R/hr)	10^8	10^9
Thermal Neutron Flux (nv)	$8x10^{13}$	$8x10^{13}$

Water Chemistry	Normal
pH (600 F) calculated	6.8 - 7.8
pH (77 F)	4.8 - 8.5
Chloride as CL^-	< .15 PPM above 200 F
Fluoride as F^-	< .15 PPM above 200 F
Oxygen as O_2	≤ .1 PPM above 250 F
LiOH as Lithium	.2 PPM
H_3BO_3 as Boron	< 1875 PPM
N_2H_4	.1 - 1.0 PPM below 200 F
H_2	15.0 - 40.0 standard cc/kg H_2O

3.4.4 Design Life

Equipment, materials and components are designed for a period of 40 years of operation in the normal and accident environments specified above. Components for which a 40-year life expectancy could not be reasonably assured are designed to permit replacement.

4.0 DESIGN FEATURES

4.1 Description

The ICC Monitoring System is based on the use of reactor vessel level monitoring, core exit thermocouples, subcooling margin and superheat temperature monitoring and hotleg water level monitoring. Data acquisition, computation, and display of the information are provided by the Inadequate Core Cooling Monitoring and Display System (ICCMDS). Each of these is described below.

4.1.1 Reactor Vessel Level Monitoring

The system consists of two (2) redundant RLIs which contain axially distributed differential thermocouples (DTCs). Associated cabling and signal processing hardware and software and also part of the monitoring system.

4.1.1.1 Radcal Level Instruments (RLIs)

4.1.1.2 Reactor Vessel Level Sensors

For a summary of preliminary instrument loop error calculations for the reactor vessel level loops, see Table 4.

4.1.2 Core Exit Thermocouples (CETs)

At present, there are 32 non-qualified CETs monitored by the plant computer and SPDS computer. This provides redundant displays of CET information. During the next refueling outage (1R7), sixteen (16) qualified CETs will be installed in order that four (4) qualified CETs will be located in each core quadrant. After installation these CETs are considered a complete Class 1E system from the sensors to the monitoring and display devices. The signals from the ICCMDS are input to the SPDS in the control room. The displayed temperature range is 100°F-2300°F. The locations of the 16 qualified CETs are shown in Figure 2.

Each data acquisition channel in the ICCMDS may accept up to twenty-four (24) type (k) chromel-alumel grounded thermocouples. Sixteen (16) of the input assignments per channel are to be spare after the 1R7 outage. However as eight (8) additional qualified CETs (4 per channel) will be added during the eighth refueling outage (1R8), only twelve (12) will then remain spare.

For a summary of preliminary instrument loop error calculations for the core exit thermocouples, see Table 6.

4.1.3 Subcooling Margin and Superheat Temperature Monitoring

The existing subcooling margin monitoring system is adequate for inadequate core cooling indication. The system is totally Class 1E with indication on a control room panel based on RCS pressure and hot leg temperature.

The ICCMDS also provides subcooling margin and superheat temperature monitoring which is based on the core exit thermocouple temperature average, reactor coolant system pressure, and saturation data extracted from steam tables and included in the microprocessor system software.

The following processing inputs are used in calculating subcooling margin and superheat temperature:

- One 4-20 mA RCS pressure input
- Calculated average core exit temperature

4.1.4 Hotleg Water Level Monitoring

As shown in Figure 3, hotleg water level monitoring is based on one (1) wide range and four (4) narrow range differential pressure measurements per hotleg. The wide range covers nearly the full-length of the hotleg from top to bottom. The four (4) narrow range transmitters per hotleg are used to increase the accuracy of the level measurement and to monitor water level in four (4) areas of interest to the plant operator during an ICC event. Additionally, the narrow range monitors provide for redundancy in the measurement of hotleg level. The range which each of the transmitters covers is as follows (see Table 5 for detailed range information):

The following process inputs are used in calculating the hotleg water level (per channel):

- Narrow Range
  - Four 4-20 mA differential pressure inputs
  - Four four wire, 100 Ohm platinum RTDs (for reference leg temperature compensation, one per narrow range transmitter.
- Wide Range
  - One 4-20 mA differential pressure input
  - One four wire, 100 Ohm platinum RTD (for reference leg temperature compensation)
- Process Temperature Compensation

Valid CET average values are used for process (hotleg fluid) temperature compensation. If a CET average value is invalid, such as CETs being removed during refueling, a default value is addressed in the program.

For a summary of preliminary instrument loop accuracy calculations for the hotleg level loops, see Table 5.

4.1.5 Inadequate Core Cooling Monitoring and Display System (ICCMDS)

The ICCMDS is a Class 1E microprocessor based system having two fully independent and redundant hardware and software channels.

Each of the redundant channels is capable of data acquisition, signal conditioning and processing, computing, display of information locally, and providing hardware and software capability and proper isolation for non-Class 1E serial communication channels to the SPDS. It has been designed to comply with the requirements of NUREG-0737, Item II.F.2 and Regulatory Guide 1.97, Rev. 3 for the variables defining the reactor coolant inventory status. Figure 4 provides a functional block diagram of the ICCMDS. Table 2 provides a listing of ICCMDS parameters, descriptions, and the ranges of the various inputs.

The system monitors and displays the following key parameters.

- Reactor Vessel Coolant Level
- Subcooling Margin and Superheat Temperature
- CET Average Temperature
- Hotleg Water Level
- Reactor Vessel Head Fluid Temperature

Additional monitoring capabilities and displayed information are described in sections 4.1.6, 4.1.7, 4.1.8, and 4.1.9.

4.1.6 Cold Junction Thermocouple Temperature Monitoring

4.1.7 Decay Heat Suction Level Monitoring

4.1.8 Reactor Coolant Pump (RCP) Status Monitoring

4.1.9 ICCMDS Cabinet Temperature Monitoring

The information provided by the three (3) RTD's located in the system cabinets is also used for monitoring of cabinet temperature. A trouble alarm is activated when high temperature is detected and the temperature of the cabinet is displayed on the local FDU.

4.2 Response Characteristics

The ICC Monitoring System has the following response characteristics:

4.2.1 Data Acquisition System

All input parameters are sampled at a rate of at least once per second.

4.2.2 Radcal Level Instruments (RLIs)

In the RLI, sensitivity of the output signal to a change in water level is maximized within the limits of the heater cable power output and overheating considerations.

4.3 System Hardware

4.3.1 Microprocessor System

4.3.2 Data Acquisition System

4.3.3 RLI Heater Power Supply

Two variable power supplies (one per train) are required for supply of heater current to the RLI heater. The power supplies are mounted near the bottom of the system cabinet(s).

4.3.4 Instrument Loop Power Supply

Two 30 Volt DC power supplies per train are provided for the wide range and narrow range hotleg water level differential pressure transmitters. The instrument loops are individually fused such that a failure of one instrument loop will have no effect on the other.

4.3.5 Thermocouple Cold Junctions

Each of the system cabinets contains termination devices with cold junction temperature monitoring sensors for termination of the chromel-alumel thermocouples.

4.3.6 Serial Communications

4.3.7 System Alarms

4.3.8 System Status Indicators

4.3.9 Calibration of the ICC Monitoring System

4.3.10 Validation

4.3.11 System Functional Tests

4.4 System Software

4.4.1 General

4.4.2 Software Design Requirements

4.4.2.1 Automatic Restart and Initialization

4.4.2.2 System Diagnostics

4.4.3 Program Functions

The ICCMDS software functions in the "Calculator" (active) mode and the "Monitor" (passive) mode. Each is described below.

4.4.3.1 Calculator Mode

- Mimic lines or areas depicting same content is colored uniformly throughout the mimic.
- Avoidance of overlapping of mimic lines.
- Commonly used graphic symbols.

4.5.1 Mimic Display Panel Functional Requirements

The functional requirements for each of the displays referenced in section 4.1.5 are included below.

4.5.1.1 Reactor Vessel Above Core Level Indication

4.5.1.2 Hotleg Water Level (Narrow Range) Indications

4.5.1.3 Hotleg Water Level (Wide Range) Indication

4.5.1.4 Core Exit Thermocouple Average Temperature

- For each channel, one (1) digital panel meter with 4 digit LEDs is provided for display of average CET temperature.

- The average of all valid CET inputs is used in calculating the display output.

- Any "suspect" CET is automatically removed from the average calculations.

- It is possible to manually delete a "suspect" CET from scan and still compute an average.

- An ICCMDS <u>trouble</u> alarm is activated when sensor failure is determined by the data acquisition system sensor validity check.

- An ICC <u>event</u> alarm is activated when calculated average core exit temperature exceeds a predetermined high setpoint value.

4.5.1.5 Subcooling Margin and Superheat Temperature

- For each channel, one (1) digital panel meter with 3 digit LEDs (including ± sign) for display of calculated subcooling margin temperature and superheat temperature is provided.

- Only the valid inputs are used in the calculation.

- An ICCMDS trouble alarm is activated when sensor failure is detected by the data acquisition system validity check.

- An ICC event alarm is activated when calculated subcooling margin temperature value falls below the setpoint.

In addition to the above referenced monitoring system indications, the following are also provided on the Mimic Display Panel.

4.5.1.6 Reactor Vessel Head Fluid Temperature

4.5.1.7 Monitor Mode Indication

For each display channel, one LED indication is provided to alert the operator that the system is in the "Monitor" mode and that other displays are not being updated.

4.5.1.8 Reactor Coolant Pump Status Indication

For each display channel, one LED indication is provided to alert the operator that any one of four reactor coolant pumps is "ON". Under this condition (Normal Plant Operation), the hotleg water level (narrow and wide range) and the reactor vessel level, below the upper plenum plate are invalid.

4.5.2 Mimic Display/Indication Panel Test

For each train on the Mimic Display Panel, the Display Test Switch actuation turns on all LED bargraphs, individual LEDs, and all display segments of the digital meters.

4.6 Fluorescent Display Units (FDU)

4.6.1 General

4.6.2 Fluorescent Display Unit Functional Requirements

The FDU provides the user with the means to identify each alarm type and to isolate the cause for the alarm condition to a given input or inputs. Displays are provided for the various alarms identified in Table 3.

In addition, the following displays are also provided on the FDU.

5.0 CONSTRUCTION AND PERFORMANCE REQUIREMENTS

5.1 Control of ICC Monitoring System Components

Components for the ICC Monitoring System have been manufactured in accordance with the various contractor quality assurance programs. These programs require that suppliers implement inspection programs, purchase materials in accordance with applicable codes and standards, and that cleanliness of the components is maintained during shipment to the installation site. Quality Assurance, as it applies to the major contractors for this project is discussed in Section 9.0.

5.2 Electrical System

5.2.1 Installation

Connectors and cabling to transmit the instrument signals and heater power between the reactor vessel and the control room are to be field installed and terminated by AP&L to existing electrical penetrations in the containment boundary.

In accordance with NUREG-0737, Item II.F.2, all electrical equipment is Class 1E and includes these features:

- LOCA-resistant connectors;
- Radiation-resistant insulated thermocouple extension wires for the in-containment section between connectors; and
- Two independent channels with non-common fault redundance.

Installation of cabling and connector for CETs and pressure transmitters is addressed in Sections 5.4.4 and 7.1.

5.2.2 Power Source

The ICCMDS operates from an electrical source with the following specifications:

Voltage:	107-132 Vac
Frequency:	60 ± 0.5 Hz
Phase:	single
Total harmonic distortion:	5%
Power:	
Cabinets	425 Watts
Mimic	85 Watts

5.2.3 Arrangement

5.2.7 Signal Cabling

5.3 Mechanical Construction

5.3.1 Instrument Nozzle and Closure Flange

5.3.2 Hotleg Level and Decay Heat Line Tap Nozzle(s).

The hotleg level nozzle shall be Inconel SB-167 and furnished in the cold worked annealed condition, while the spool piece is seamless stainless steel SA-312, Type 316 furnished in the solution annealed condition. The assembly welds are to be examined in accordance with ASME Code, Section III requirements and NPT stamped as a Class 1 piping subassembly. The tap sleeve material is to be Inconel SB-166, cold worked annealed condition.

The decay heat line tap nozzle is stainless steel SA-479 Type 316 furnished in the solution annealed condition. Nozzle base material is to be ultrasonically examined in accordance with SA-745. The nozzle external surfaces are to be PT examined per ASME Section III.

5.3.3 ICCMDS Hardware

A detailed list of the hardware associated with the ICCMDS is provided in Table 1.

5.4 Installation

5.4.1 Sensor Locations

There are 10 sensors in each RLI, including the ATC sensor located at the uppermost position. The location of these sensors is as follows:

5.4.2 Radcal Level Instrument (RLIs)

The RLIs are designed to satisfy the following mechanical requirements:

- The RLIs can be inserted through the existing control rod drive mechanism flanges, from the top of the reactor vessel down to the fuel alignment plate.
- The RLIs are supported inside the guide tubes by standoffs to prevent contact between the RLI and the guide tube at positions near any sensor. Standoffs are located at a distance far enough from the sensors to prevent detrimental effects on their signals.

- The RLIs are strong enough, or are supported by guide tubes, to withstand, without permanent strain or damage to sensor operation, the hydraulic forces and vibration expected during normal and accident conditions.

5.4.3 Manometer Tubes

The RLIs are surrounded by manometer tubes which are contained in existing control rod assembly tubes. The manometer tubes enable the RLIs to sense collapsed liquid level. Hydraulic isolation is provided between the dome and plenum areas.

5.4.4 Core Exit Thermocouples (CETs)

Sixteen (16) qualified incore thermocouples and assemblies will be installed in the locations identified in Figure 2. Installation details are provided in section 7.1.

5.4.5 ΔP Transmitters and Tap Assemblies

Transmitters are to be installed on the outer side of the secondary shield wall. Tap assemblies are being installed in locations identified in Figure 3 and Table 5. Further discussion of materials and installation procedures is provided in Sections 5.3.2 and 7.1, respectively.

6.0 TESTING PROGRAM

6.1 Prototype Testing

TEC and AP&L designed and conducted an extensive experimental program on the RLI to verify ICC monitoring capability, and to provide licensing support and design data for the system hardware for ANO-1 and ANO-2. The test program was conducted at the Oak Ridge National Laboratory (ORNL), using two atmospheric air/water test facilities and the pressurized water Forced Convection Test Facility (FCTF). The air/water facilities were used to provide manometer tube design data and basic sensor response parameters.

The FCTF is a typical reactor simulation facility that has been used in several NRC programs. It has both blowdown and reflood capability with sufficient control and instrumentation systems to perform the tests required to simulate a reactor under small-break LOCA conditions.

The detailed tests and analyses are presented in Section 6.2.

6.1.1 Overall Test Objectives

The overall objectives of the test program were:

- to verify that the proposed manometer tube design permits unambiguous coolant inventory determinations (above-core),
- to confirm that the RLIs will detect ICC conditions, and
- to identify the boundary conditions for unambiguous ICC indications.

6.1.2 Air/Water Test Objectives

The overall objectives of the air/water test series were:

- to provide basic design data on the manometer tube stilling column and RLI assembly's performance,
- to demonstrate that the final prototype manometer tubes and probes can make level measurements in a variety of air/water mixtures and flows,
- to obtain basic performance data, response time, and fill and drain rates of the manometer tube/RLI assemblies, and
- to determine the boundary conditions of flow and void fraction under which the RLI assembly can provide unambiguous data to a reactor operator.

6.1.3 Upper Head Test Objectives

The overall objectives of the Upper Head Test Series were:

- to demonstrate that the prototype RLI can supply measurements to provide effective ICC monitoring of the upper head and plenum region of the reactor,
- to provide data to determine the boundary conditions for unambiguous ICC monitoring performance [depressurization rates (break size), flow rates (pumps-off sensitivity), and refill rates (repressurization)],
- to confirm that absolute temperature measurements provide a clear indication of coolant temperature above the core in an ICC event, and
- to provide data to select the optimum sensor types and arrangements in the RLI.

6.1.4 Overall Conclusions

Variations in blowdown rate, reflood rate, initial temperature, and initial flow were included within the parameters of the test series. Three sensor types and three gas-gap length variations within the "fast" and "slow" sensor types were tested. The overall conclusions were:

- All RLI's maintained their mechanical integrity, operability, and performance throughout the tests.
- All RGT sensor types respond well to blowdown and reflood transients and could be used as ICC warning devices with fairly simple type-specific data processing.
- Inventory loss or gain rate can be determined in addition to inventory.
- The response of the sensors is predictable, including variations in absolute temperature and flow.

6.2 Post Fabrication Testing

6.2.1 Overall Testing

After fabrication, all RGT sensors are to be functionally tested to determine that the sensor response was correct. Actual response will be compared to expected results based on analyses and/or earlier testing. The RGT sensors will be calibrated after fabrication to determine the sensor thermal sensitivity. This sensitivity is combined with the analytically determined coupling coefficient to produce overall instrument factors. The RGT sensor calibration simulated gamma heating by volumetric (or Joule) electric heating, and also by using the RLI heater cable.

RGT signals can be fed directly to the control room without intervening electronics. The signal is adequate and no amplification is required.

Testing of the ICCMDS will include approximately 96 hours of burn-in testing and also a system integration test. The data acquisition hardware and software will be functionally tested to determine correct acquisition, processing, and display of the sensor signals. This testing includes insertion of known input values to simulate sensor output signals. Output signals will be compared to expected values and both channels of the data acquisition software will be compared to verify that the same output signals will occur for the same input signals.

The ICCMDS was functionally tested in July, 1986 in accordance with factory acceptance test procedures. The tests will be conducted to verify that the system conforms to the functional requirements of the AP&L design specification. After installation at ANO-1, site acceptance tests will also be performed utilizing site specific setpoints.

6.2.2 Calibration Tests

6.2.2.1 Constancy of Calibration

6.2.2.2 Accurate Out-of-Reactor Calibration

The sensitivity of RGT signals to heating of the sensors can be measured in a laboratory by direct electrical heating or by time constant determination. In practice to date, a variation of plus or minus 1.5% in mean sensitivity has been demonstrated at French PWRs. Individual chambers have shown high linearity of signal (correlation coefficient greater than 0.9999 to the best fit straight line) in both room temperature and high-temperature (300 degree C coolant) electrical heating calibration.

6.2.2.3 In-Core Recalibration

Testing was performed using heater cables in RGT specimens that gave calibration curves with linearity and scatter as good as those obtained by direct electrical calibration.

In the application of the heater calibration technique, the process heat being generated in any RGT string at any time (usually 0 to 3.0 W/g) is augmented by up to 3 W/g of electric heating by the mineral insulated nichrome cables imbedded in the cable pack. This full-range recalibration can be done at any time that it is required (or desired), and at full or reduced reactor power.

6.2.2.4 RGT Calibration

Calibration was rechecked for the test specimen prototype during the hot testing program (depressurization tests) to determine cold-to-hot calibration constants.

7.0 INSTALLATION, TESTING, AND MAINTENANCE

7.1 Installation

All cable runs from the hotleg sensors to the penetrations shall be routed in channelized raceways. All terminations inside containment shall be sealed with environmentally qualified splice kits.

The following additional instrumentation tap assemblies are to be installed to accommodate the hotleg water level monitoring system;

- 4 in the "B" loop hotleg piping,
- 3 in the "A" loop hotleg piping,
- 1 in the decay heat line (off the "A" loop hotleg piping).

See Figure 3 for the hotleg level instrumentation arrangement.

7.2 Post 1R7 Modifications

In addition to the modifications described in Section 7.1, further modifications are planned for the eighth refueling outage (1R8). During 1R8, currently scheduled to commence in May 1988, eight (8) additional incore CETs will be installed. The proposed locations of the additional CETs is shown in Figure 2. Those are not being installed during the 1R7 outage since there is additional useful life remaining in the existing incore detectors.

8.0 TRAINING AND PROCEDURE REVISIONS

8.1 Training

Training programs for the ICC Monitoring System will be conducted utilizing both operation and maintenance manuals. At present, the training programs are being developed to encompass operator training as well as hardware and software maintenance training. It is planned that the training program will be conducted in conjunction with ExoSensors for a duration of approximately one week. A brief summary of the contents of each training program is given below.

Additional training will be conducted after completion of EOP revisions and necessary operating procedure modifications.

8.1.1 Operator Training

This course will provide a general system overview from an operations standpoint. Block-diagram level discussions will be held regarding system configuration, system startup, and alarms. Such discussions will provide the information required to operate the system from any operator device.

8.1.2 Hardware Maintenance Training

This course will consist of an overview of the system configuration and communication logic of the system. Sessions will include calibration, display functions, control functions, and diagnosing of system hardware problems.

8.1.3 Software Maintenance Training

This course will provide an overview of the system software. System software configuration and database philosophy will be covered, to include system startup, device tables, data acquisition, and diagnostics.

8.2 Control Room Design Review (CRDR)

In accordance with the Order for Modification of License, the task analysis portion of the CRDR has been completed.

8.3 Human Factors Engineering (HFE)

NUREG-0737, Item II.F.2 (ICC and CETs) requires that: Types and locations of displays and alarms should be determined by performing a human-factors analysis taking into consideration:

- the use of this information by an operator during both normal and abnormal plant conditions,
- integration into the EOP,
- integration into operator training, and
- other alarms during emergency and need for prioritizing alarms.

HFE reviews have been conducted in order to comply with the requirements based upon present status of the project. Additional reviews will be conducted as necessary.

8.4 Emergency Operating Procedure (EOP)

EOP Technical Guidelines addressing ICC monitoring have been developed. After NRC approval of the guidelines, the station EOP will be modified to provide guidance for utilizing the reactor vessel monitoring system.

9.0 QUALITY ASSURANCE

9.1 Arkansas Power and Light Company (AP&L)

AP&L's quality assurance program, as documented in the Quality Assurance Manual, APL-TOP-1A, Revision 7, complies with its referenced Regulatory Guides.

9.2 Contractor Quality Assurance Programs

Various contractor quality assurance programs and procedures have been implemented during the design, manufacturing, testing, and qualification of the ICC Monitoring System components, system hardware, and related software. The applicability of the individual contractor quality assurance programs, is dependent upon the scope of responsibility of the individual contractors.

9.2.1 Technology for Energy Corporation (TEC)

The manufacture, testing, and qualification of the RGT probes was conducted in accordance with the TEC Quality Assurance Program and implementing procedures. The program addresses the requirements of ANSI N45.2-1977, and 10CFR50, Appendix B. The implementing procedures used in TEC's quality assurance program are contained in the TEC QA Manual. The procedures comply with ANSI Standard N45.2 insofar as they are applicable to the project requirements. TEC's quality assurance program applies to all contracts or QA purchase orders designated by TEC's customers as having quality assurance requirements.

TEC applied the referenced QA program during manufacture of the test specimens and during all phases of design, manufacture, testing and equipment qualification.

All shipping, packaging and handling has been performed in accordance with ANSI N45.2.2, Level B. Further details are in TEC's Quality Assurance Plan and Quality Assurance Manual. The TEC Quality Assurance Manual was submitted to AP&L for review prior to initiation of equipment fabrication.

9.2.2 Babcock and Wilcox (B&W)

B&W is responsible for the design of the hotleg level sensing taps and supply of incore thermocouples and detectors with connector assemblies, and RLI supports and housings. The applicable portions of the B&W quality assurance program have been implemented during the manufacturing and testing of such components.

9.2.3 ExoSensors

ExoSensors has developed and implemented a quality assurance program during the project. The prime responsibility of ExoSensors has been to furnish the display cabinets and the Mimic Display Panel. The ExoSensors quality assurance program has been implemented for suppliers of components or for firms providing services to them. A software quality assurance plan, utilizing IEEE 730-1984 as a guide includes, independent software verification and validation. ANSI/IEEE-AWS-74.3.2-1982 guides the overall development of the Class 1E microprocessor system.

These documents, referenced in section 11.3, have been submitted to AP&L for review and approval.

9.3 Safety Classification

The ICC Monitoring and Display System (ICCMDS) is classified as Class 1E and satisfies the requirements of IEEE 323-1974, IEEE 344-1975, and IEEE 384-1981, except for the SPDS, which is classified as non-Class 1E. The system is classified as Seismic Category I, except for the SPDS. Hotleg ΔP transmitters, reference leg RTD sensors, signal transmission system, and signal processing system up to and including the isolators are seismically and environmentally qualified in accordance with IEEE 323-1974 and IEEE 344-1975.

The RLIs, signal transmission system, and the signal processing system up to and including the isolators are seismically and environmentally qualified in accordance with IEEE 323-1974, IEEE 344-1975, and IEEE 384-1981.

Incore thermocouples and connector assemblies are environmentally qualified and have been tested in accordance with IEEE Standards 323-1974, and 344-1975.

ANO-1 presently has 32 monitoring core exit thermocouples located at the top of the 52 in-core instrument detectors. At present the sensors, electrical connectors, and signal processing equipment are non-Class 1E. During 1R7, the CET instrumentation system is being upgraded by installing sixteen (16) qualified CETs. The ANO-1 incore instrument cables and connectors were procured as prefabricated cable assemblies. The procurement documents required that the assemblies be manufactured and tested in accordance with IEEE Standards 323-1974, and 344-1975. B&W supplied the prefabricated tested assemblies with certification to demonstrate that the materials and assemblies complied with the procurement specifications.

The design of the level tap assemblies (excluding valves), materials, fabrication, and installation (welding and NDE) of all parts and subassemblies is in accordance with the requirements for Class 1 piping per 1980 edition of ASME Section III with Addenda through Winter 1981.

9.3.1 Test Results

10.0 CONFORMANCE ANALYSIS

10.1 Reactor Vessel Level Monitoring System

The RLI will give an early warning of the approach to ICC. The sensors are axially located to provide optimum resolution in the areas of most concern. The system was intended to incorporate a segmented manometer tube that would differentiate the upper head region and the plenum region.

10.1.1 Advantages

The advantages of using RLIs for level measurement are that:

- No density compensation is required.
- There is a large and easily detectable signal change with a phase change of coolant surrounding the sensor.
- The RLI is simple in design and sturdy in construction.
- The signal transmission system design is straightforward.

10.1.2 Environmental Qualification

The RLIs, signal transmission system, and signal processing system up to and including the isolators are seismically and environmentally qualified as described in Section 9.3. The SPDS is non-Class 1E, but is backed by the Class 1E Mimic Display Panel.

10.1.3 Single Failure Analysis

For reactor vessel level measurement, two RLIs are being installed. Electrically, the two RLIs are separate, and two channels of diverse cable routing are maintained all the way to the Class 1E data acquisition unit. The non-Class 1E display (SPDS) is supplied (through isolators) from the data acquisition and control unit.

10.1.4 Class 1E Power Source

All portions of the system are provided with Class 1E power with the exception of the SPDS computer (with its own inverter power supply and battery backup), relays for RCP contacts, and power source for annunciators.

10.1.5 Availability Prior to an Accident

Because the system is composed of two redundant channels, one channel may be temporarily removed from service for surveillance testing, calibration or maintenance while the other channel remains in service, thus insuring system availability.

10.1.6 Quality Assurance

See Section 9.2.1 and 9.2.3

10.1.7 Continuous Indication

Reactor vessel level information will be continuously provided at the Mimic Display Panel and the SPDS along with other inputs. Any information provided to the SPDS is available to be displayed in the human-factored color graphics console at operator request. The information is also displayed on the FDU.

10.1.8 Recording of Instrument Outputs

Recording of reactor vessel level information is performed by the trending capabilities of the SPDS computer. The trend information is stored by the computer and is available for display on demand.

10.1.9 Identification of Instruments

The data acquisition system is a dedicated, modular unit for which the control panel serves only ICC monitoring functions. As such, it is clearly identifiable for the purpose of obtaining reactor vessel level information.

10.1.10 Isolation

The RLIs, signal transmission system, and display/control unit are all Class 1E components. Where isolation is required, as in the output to the SPDS, qualified isolation is provided.

10.1.11 Channel/Monitor/Sensor Check and Test

Periodic validation of sensor signals, monitors, and channels is possible during operation. For the purpose of surveillance testing or repair, one channel of the data acquisition system may be taken out of service for a short period without affecting the operation or the validity of signals in the other channel.

By using the heater current indication, step changes in heater current added to the existing sensor input signal should result in a proportionally similar increase in output signal for any sensor. Hence, signals can be checked for similar response and, if necessary (under access control), constants can be changed during plant operation to correct discrepancies.

The system is capable of executing startup software self-diagnostics for the detection of hardware and software failures.

Except for the in-containment components, the reactor vessel monitoring system can be repaired during plant operation. There is no in-containment signal conditioning equipment.

10.1.12 Access Control

The data acquisition system is provided with "Access Control". Timed passwords are provided to enable maintenance personnel access for a specific period. A timed password is valid until the expiration date and time entered for that password.

10.1.13 Adjustments

Access to setpoints, calibration constants and test points for reactor vessel level monitoring is under access control.

10.1.14 Invalid Indications

During operation, the data acquisition system removes from service and discontinues value displays for any failed sensor or shorted or open circuit. Such failure is clearly flagged. The operator can remove from service any failed sensor.

10.1.15 Direct Input

Signals from the RGT sensors are input directly into the data acquisition system without prior signal amplification or noise filtering. A temperature reference junction is required for the CETs.

The signals from the RGT sensors are self-powered, directly producing a millivolt signal to the data acquisition systems for conditioning. Differential thermocouples are equipped with electric heaters.

10.1.16 Normal Use

The reactor vessel level monitoring system may be used by the operators during the filling and venting phases of reactor startup, as well as the cooldown and draindown phases of reactor shutdown.

10.1.17 Periodic Testing

The reactor vessel level monitoring system is designed to accommodate periodic testing. As part of a Class 1E system, the ICC instruments will be subjected to normal surveillance testing in accordance with the ANO-1 Technical Specifications.

10.1.18 Emergency Operating Procedure

Emergency Operating Procedure Technical Guidelines have been developed for guidance on use of the reactor vessel level monitoring system. Upon NRC approval of the guidelines, the station EOP will be updated.

10.2 Subcooling Margin and Superheat Temperature

The existing subcooling margin monitoring system based on RCS pressure and hot leg temperature has been previously installed and approved by the NRC by letter 1CNAØ883Ø1 dated August 5, 1983. Details of this system were provided by a letter to the NRC dated January 18, 1980 (ØCANØ18Ø22). In addition, the ICCMDS also provides the capability to monitor subcooling margin/superheat temperature utilizing CET average temperature instead of Hot Leg temperature.

10.3 Core Exit Thermocouples (CETs)

NUREG-0737, Item II.F.2 states: The instrumentation must be evaluated for conformance to Appendix B, "Design and Qualification Criteria for Accident Monitoring Instrumentation," as modified by the provisions of items 6 through 9.

Significant upgrading is being undertaken to make this a Class 1E system up to and including the Mimic Display Panel with suitable isolators for the non-Class 1E display.

10.3.1 Arrangement

Figure 2 shows the locations of the in-core instrument assemblies after the 1R7 outage. The CETs are part of the in-core instruments. Additional CETs will be installed during 1R8 as discussed in section 7.2.

10.3.2 Primary Display

The SPDS computer is the primary display. Its color graphic capabilities provide a core map with CET temperatures. Individual CET temperatures may also be displayed at operator request.

10.3.3 Temperature Range

The CETs have a range of 100° F to 2300°F. Readings that are out-of-range high or low cause an alarm on the alarm CRT of the computer. This alerts the operator of possible equipment failure. Out-of-range and suspect readings are excluded from calculation of the CET average.

10.3.4 Backup Display

The backup displays for the ICCMDS are the Class 1E Mimic Display Panel and the Fluorescent Display Unit attached to the microprocessor cabinets which have input signals from 24 CETs (16 to be installed during 1R7 and 8 to be installed during 1R8). Operability of the backup units is checked by periodic surveillance and calibration. The range of the CET displays are 100°F to 2300°F.

10.3.5 Use of the Display

Use of the SPDS display will be as described in the Emergency Operating Procedure (EOP). The backup displays will be used when the primary display is unavailable. The SPDS provides the core exit temperature information that the operator needs for an ICC event. This information will be called for by the EOP at the time it is required.

The CETs are also used to provide backup indication for reactor outlet RTDs (hot leg temperature).

10.3.6 Training

The training program will include procedure training that specifies which indications to monitor and what actions to take based on the indications.

10.3.7 Environmental Qualification

All parts of the CET monitoring system will be environmentally qualified. See Section 9.3 for details regarding environmental qualification for the CETs.

10.3.8 Single Failure Analysis

The system is single failure proof up to and including the final electrical isolation devices in the signal processing equipment. From this point, both channels feed the common SPDS display. The SPDS was designed to approach 99% availability. The CET inputs to the backup display are derived from each of the channels.

10.3.9 Class 1E Power Source

Each channel from the CETs up to and including the final electrical isolator in the signal processing equipment, and the backup display, is powered from its own, independent, Class 1E power source. The SPDS is powered from a highly reliable non-Class 1E inverter that is fed from a safety bus with battery backup.

10.3.10 Availability Prior to an Accident

CET information is available continuously. Because of the redundant channel design, a channel can be out of service for calibration or maintenance for short periods while the other channel remains in service.

10.3.11 Quality Assurance

See Sections 9.2.2 and 9.2.3

10.3.12 Continuous Indication

The operator can select and display, continuously on demand, CET temperature information via the SPDS and the Mimic Display Panel. The operator must manually select the desired CET location to monitor on the SPDS. Since all CETs monitor temperature over the same range, there are no gaps in the measurement.

10.3.13 Recording of Instrument Outputs

Recording of CET temperature information is performed only on the SPDS, using its trending capabilities. Trend information is temporarily stored by the computer and is available for display on demand.

10.3.14 Identification of Instruments

The SPDS, as the primary display system, is recognized as being useful for monitoring and assessing accident conditions. The backup display is also available for use as an accident monitoring device.

10.3.15 Isolation

See Section 9.3.

10.4 Hotleg Water Level Monitoring

Hotleg water level monitoring is based on the use of one (1) wide range and four (4) narrow range ΔP pressure transmitters per hotleg.

10.4.1 Arrangement

Figure 3 provides a diagram identifying the locations of the individual transmitters and pressure taps on both trains of the "A" hotleg. (Also see Table 5 for detailed range information.)

10.4.2 Primary Display

The SPDS is the primary display for hotleg water level monitoring.

10.4.3 Range of Pressure Transmitters

See Table 5 for the range of the differential pressure transmitters.

10.4.4 Backup Display

The backup display for hotleg water level monitoring are the Class 1E Mimic Display Panel and the Fluorescent Display Unit attached to the microprocessor cabinets. Operability of the backup unit is checked by periodic surveillance and calibration.

10.4.5 Use of the Display

Use of the display will be as described in the Emergency Operating Procedure (EOP). The backup display will be used when the primary display is unavailable.

10.4.6 Training

The training program will include procedure training that specifies which parameters monitor and what actions to take based on the indications.

10.4.7 Environmental Qualification

The transmitters, RTDs, and connectors have been qualified in accordance with IEEE 323-1974 and IEEE 344-1975. Qualification test reports have been submitted by contractors.

10.4.8 Single Failure Analysis

For hotleg level measurement, two redundant channels of differential pressure transmitters are being installed per hotleg.

10.4.9 Class 1E Power Source

All portions of the system are provided with Class 1E power with the exception of the SPDS computer.

10.4.10 Availability Prior to an Accident

The system has been designed to provide 99% availability. With any RCP running the level information is invalid.

10.4.11 Quality Assurance

Transmitters, RTDs, and connectors have been procured in accordance with the quality assurance requirements of Appendix B to 10CFR50.

10.4.12 Continuous Indication

Hotleg water level information will be continuously provided at the SPDS and the Mimic Display Panel along with other inputs. Information provided to the SPDS is available for display in the human-factors color graphics console. Information is also capable of being displayed on the FDU.

10.4.13 Recording of Instrument Outputs

Recording of hotleg water level information is performed by the capabilities of the SPDS computer. The information is stored by the computer and available for display on demand.

10.4.14 Invalid Displays

A low out-of-electrical limits failure of a differential pressure transmitter while the RCPs are running will cause the hotleg level bargraph associated with that transmitter to be turned off. When the RCPs are not running a hi out-of-electrical limits signal will also cause the bargraphs to be turned off.

10.4.15 Identification of Instruments

The data acquisition system is a dedicated unit for which the panel serves only ICC monitoring functions. It is clearly identifiable for purposes of obtaining hotleg level information.

11.0 REFERENCES

11.2 Babcock and Wilcox

11.2.1 Document #49-1021166-02, Nuclear Qualification of Incore Thermocouples, Incore Detector, and Connector Assemblies, Dated June 14, 1984.

11.2.2 Document #51-1159663-00, Installation and Operating Instructions for Gamma Thermometer and Related Hardware.

11.3 ExoSensors

11.3.1 Qualification Plan for ICC Monitoring and Display System, EXO-QP-119.

11.3.2 Software Qualification Plan for ICCMDS at ANO-1, dated April 7, 1986, EXO-QAP-064

11.3.3 Software Verification Plan, dated April 9, 1986, EXO-SVP-066.

11.4 Nuclear Regulatory Commission (NRC)

11.4.1 NUREG-0737, Clarification of the TMI Action Plan Requirements

11.4.2 Supplement 1 to NUREG-0737, Requirements for Emergency Response Capability

11.4.3 Appendix B to 10CFR50, Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants

11.4.4 10CFR50.49, Environmental Qualification of Electrical Equipment for Nuclear Power Plants

11.4.5 Regulatory Guide 1.100, Seismic Qualification of Electrical Equipment for Nuclear Power Plants

11.4.6 Regulatory Guide 1.26, Quality Group Classification and Standards for Water, Steam, and Radioactive Waste Containing Components of Nuclear Power Plants

11.4.7 Regulatory Guide 1.63, Electric Penetration Assemblies in Containment Structures for Water Cooled Nuclear Power Plants

11.4.8 Regulatory Guide 1.75, Physical Independence of Electrical Systems

11.4.9 Regulatory Guide 1.89, Qualification of Class 1E Equipment for Nuclear Power Plants

11.4.10 Regulatory Guide 1.97, Instrumentation for Light-Water Cooled Nuclear Power Plants to Assess Plant and Env Conditions During and Following an Accident

11.5 American Society of Mechanical Engineers (ASME)

11.5.1 ASME Boiler and Pressure Vessel Code, Section III

11.5 American National Standards Institute (ANSI)

11.5.1 ANSI N45.2, Quality Assurance Program Requirements for Nuclear Power Plants

11.5.2 ANSI N45.2.2, Packaging, Shipping, Receiving, Storage and Handling of Items for Nuclear Plants

11.5.3 ANSI N45.2.4, Supplementary Quality Assurance Requirements for Installation, Inspection and Testing Requirements of Instrumentation and Electrical Equipment During the Construction of Nuclear Power Generating Stations

11.5.4 ANSI N45.2.6, Qualification of Inspection, Examination and Testing Personnel for the Construction Phase of Nuclear Power Plants

11.5.5 ANSI N45.2.8, Supplementary Quality Assurance Requirements for Installation, Inspection and Testing of Mechanical Equipment and Systems for the Construction Phase of Nuclear Power Plants

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

11.5.7 ANSI N45.2.10, Quality Assurance Terms and Definitions

11.5.8 ANSI N45.2.12, Requirements for Auditing of Quality Assurance Programs for Nuclear Power Plants

11.5.9 ANSI N45.2.13, Supplementary Quality Assurance Requirements for Preparation of Procurement Documents for Nuclear Power Plants

11.5.10 ANSI N45.2.14, Quality Assurance Program Requirements for the Design and Manufacture of Class 1E Instrumentation and Electric Equipment for Nuclear Power Generating Stations

11.5.11 ANSI N45.2.22, Supplementary Requirements for Inspection of Dimensional Characteristics

11.5.12 ANSI N45.2.23, Qualifications of Quality Assurance Program Audit Personnel for Nuclear Facilities

11.5.13 ANSI N512, Protective Coatings (paints) for the Nuclear Industry

11.6 Institute of Electrical and Electronic Engineers (IEEE)

11.6.1 IEEE 323, Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations

11.6.2 IEEE 344, Guide for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

11.6.3 IEEE 383, Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations

11.6.4 IEEE 384, Criteria for Independence of Class 1E Equipment and Circuits

12.0 FIGURES

13.0 TABLES

TABLE 1

ICC HARDWARE LIST

TABLE 2

ICCMDS PARAMETERS

TABLE 3

SYSTEM ALARMS

TABLE 4

PRELIMINARY LOOP ERROR ANALYSIS
REACTOR VESSEL LEVEL
POSITIVE (REFLOOD) AND NEGATIVE (DRAINDOWN) ERRORS

TABLE 5

LOOP ERROR ANALYSIS
HOTLEG LEVEL

Transmitter #	Upper Tap Elevation	Lower Tap Elevation	Indicated Range	Loop Accident Error To SPDS %	Loop Accident Error To SPDS Inches	Loop Accident Error To Mimic %	Loop Accident Error To Mimic Inches

TABLE 6

LOOP ERROR ANALYSIS

CORE EXIT THERMOCOUPLES

UNIT-1 REACTOR VESSEL - FIGURE 1

Z

ANO-1 CET LOCATIONS

FIGURE 2

EXISTING CET LOCATIONS

1R7 CET LOCATIONS

1R8 CETs

HOT LEG LEVEL INSTRUMENTATION

(TYPICAL ARRANGEMENT SHOWN FOR "A" HOT LEG SIMILAR FOR "B" HOT LEG)

FIGURE 3

NOT

Figure 4