ARKANSAS POWER & LIGHT COMPANY
POST OFFICE BOX 551 LITTLE ROCK, ARKANSAS 72203 (501) 371-4000

April 15, 1983

2CANØ483Ø6

Mr. Darrell G. Eisenhut, Director
Division of Licensing
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Arkansas Nuclear One - Unit 2
Docket No. 50-368
License No. NPF-6
Inadequate Core Cooling Order

Gentlemen:

Your letter dated December 10, 1982, (ØCNA128211) transmitted an Order for Modification of Licenses. This letter transmits submittals required by Sections III.2 and III.3 of the Order.

AP&L has evaluated available Inadequate Core Cooling (ICC) instrumentation systems and selected an approach based on the RADCAL gamma thermometer (RGT). Our conceptual approach was presented to members of the NRC staff in Bethesda on March 31, 1983. On April 6, 1983, a list of eight questions or concerns regarding our proposed system were transmitted by the staff via telecon. We will address these items in a separate submittal.

Since the use of RGTs for ICC application has not been previously approved by the NRC, AP&L is undertaking a program of confirmatory testing and qualification. Schedular considerations for this program are discussed briefly in our submittal. Additional submittals will be provided at key milestones shown on our schedule. During our evaluation of the Order, we have performed initial engineering on an ICC system using the CE Heated Junction Thermocouple system for in-vessel monitoring. We will continue a level of effort on this approach until our development program is completed and NRC confirms the acceptability of our system.

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We feel that our proposed system, described in Attachment 1, meets the intent of the December 10, 1982, Order. Although not required, we are proposing the installation of in-core probes to provide additional information. We urge the earliest possible NRC review and approval of our submittal to allow us to continue our efforts at implementing this innovative system.

Very truly yours,

John R. Marshall
Manager, Licensing

JRM:JK:sl

Attachments

STATE OF ARKANSAS)
) SS
COUNTY OF PULASKI)

I, John R. Marshall, being duly sworn, subscribe to and say that I am Manager, Licensing for Arkansas Power & Light Company; that I have full authority to execute this oath; that I have read the document numbered 2CAN048306 and know the contents thereof; and that to the best of my knowledge, information and belief the statements in it are true.

John R Marshall

John R. Marshall

SUBSCRIBED AND SWORN TO before me, a Notary Public in and for the County and State above named, this 15th day of April, 1983.

Carolyn Edwards

Notary Public

My Commission Expires:

4-1-85

ATTACHMENT 1

ANO-2

Proposed ICC System in Response to

December 10, 1982, Order

The proposed system for detecting and monitoring inadequate core cooling conditions consists of the following four elements:

Sub-cooled Margin Monitor
Reactor Vessel Head Level (Using Gamma Thermometer)
Core Exit Thermocouples
In-Core Monitor (Using Gamma Thermometer)

The format of this response is in accordance with Appendix A of the Order. Each element of the system is addressed, as appropriate, under items numbered 1 through 9 from Appendix A.

1. Description of the proposed final system including:

   a. A final design description of additional instrumentation and displays.

   RESPONSE:

   Reactor Vessel Head Level (RVHL)

   Two gamma thermometer probes will be installed to monitor level in the upper head and plenum regions of the reactor vessel. Each probe will contain multiple sensors distributed axially along its length. The top sensor will be an absolute thermocouple located just under the reactor vessel head. The remaining sensors will be differential heated thermocouples used for level sensing. The upper head and the plenum will be treated as separate regions. Each region will have multiple differential thermocouples for level monitoring. Figure 1 shows the conceptual installation. The Safety Parameter Display System (SPDS) computer will be used for displaying the level information. The color graphic capabilities of the SPDS can be used to provide a scaled indicator mimic giving the operator concise, unambiguous and human factored level information. The plenum region level information is not valid during reactor coolant pump operation and the display for plenum level will be inhibited or denoted as invalid during pump operation.

   The gamma thermometer installation will be accomplished by removal of two in-core instrument assemblies. Mechanically, the gamma thermometer is very similar to the in-core instrument, thus the installation is quite straightforward. Qualified signal processing hardware will be installed to isolate the qualified gamma thermometer probes from the non-qualified SPDS computer.

   Core Exit Thermocouples (CET)

   For the purpose of this discussion the core exit thermocouples (CET) are considered a complete system from the existing sensors to the monitoring and display devices, either existing or to be added. The existing system will be described in 1.b. below and the additional monitoring and display equipment to be added to the system will be described in 1.c. below.

In-Core Monitor (ICM)

The two gamma thermometer probes installed for head level will also extend down into the core. The purpose of these probes is to provide information from the reactor core. Each probe will contain multiple sensors distributed axially along its length. The sensors will be a combination of absolute thermocouples and differential thermocouples. The absolute thermocouples will be located at the core inlet and outlet areas as well as at central elevations of the core. Direct temperature readout is available from these sensors at these locations. The differential thermocouples are similarly distributed along the length of the core. The information provided by these sensors is directly related to the heat transfer conditions at the various sensor locations. See Figure 1 snowing the conceptual installation. The SPDS computer will be used to display the information from the in-core monitoring system. The color graphic capabilities will be used to provide information at different elevations corresponding to sensor locations in the core.

Installation of the gamma thermometer probes for above-core and in-core monitoring is essentially a direct replacement for existing in-core instrument assemblies. Diverse cable routing will be used to achieve the necessary separation. Signal processing hardware will be installed to isolate the qualified gamma thermometer probes from the non-qualified SPDS computer.

b. Detailed description of existing instrumentation systems.

RESPONSE:

Sub-cooled Margin Monitor (SMM)

The sub-cooled margin monitor is presently installed and operational. The details of the system were provided in our letter, dated January 18, 1980 (ØCANØ18Ø22).

Core Exit Thermocouples (CET)

ANO-2 presently has 44 radially distributed core exit thermocouples. These CETs are part of and are located in the upper portion of the in-core neutron detectors. See Figure 2 for locations of the in-core assemblies. Two of these CETs will be replaced by RGTs.

The signals from the CETs are inputs to the plant computer where they are logged and displayed via CRT in the control room upon demand by the operators. The displayed temperature range is 0-2300°F.

The CETs, including electrical connectors, do not presently serve any safety-related functions and are therefore not class 1E. They are, however, divided into channelized groups with the in-containment cables associated with each channel installed in

separate class 1E raceways to the penetrations. These in-containment cables are qualified. From the penetration outside containment, the cables are routed in non-safety related raceways to the non-class 1E plant computer.

c. Description of completed or planned modifications.

RESPONSE:

<u>Sub-cooled Margin Monitor (SMM)</u>

No modifications are planned to the SMM.

<u>Core Exit Thermocouples (CET)</u>

The proposed modifications to the CET monitoring system include (see Figure 3):

(A) Transfer of the CET inputs from the plant computer to the SPDS (primary display);

(B) Upgrading the qualification of the CETs, connectors, and cables to class 1E up to and including the isolation device;

(C) Addition of CET signal processing equipment and isolators in the loop between the sensors (1E) and SPDS (non-1E); and

(D) Addition of a qualified backup display in the control room for one channel of the CETs.

Basically, the approach is to upgrade the CET monitoring system up to and including the signal processing and isolation equipment to class 1E. Equipment qualification will be discussed later.

The CETs will be divided into two (2) channels consisting of 22 sensors per channel. The cables for each channel will be routed in separate, safety-related raceways to the signal processing and isolation equipment. This equipment will perform any signal conversion that may be necessary and isolate the signals prior to sending them to the non-class 1E SPDS computer. The equipment will be mounted in seismically qualified cabinets located in a non-harsh environmental area of the auxiliary building. All equipment for one channel will be installed in cabinets physically and electrically separated from the other channel.

From the signal processing equipment downstream of the isolator outputs, the signals from both channels will be routed in non-safety related raceways to the SPDS computer for monitoring and display. The SPDS will serve as the primary display for all 44 CET locations.

The signals for the backup display will be obtained in the signal processing equipment (prior to the isolators) for one of the channels described above and will be routed via safety-related raceways to the control room panel where the backup display will be located. As a minimum, 16 CET inputs, four (4) per core quadrant, will serve as inputs to the backup display. The backup display is class 1E from the signal processing equipment up to and including the display. It will consist of a single indicator with a multi-position switch to allow the operator to manually select the CET location of interest. The arrangement and location of the backup display will be determined separately as a part of the Control Room Design Review (CRDR).

Further description of the CET monitoring system modifications, including equipment qualification, single failure analysis, etc. will be presented in the responses to II.F.2., Attachment 1 and Appendix B.

2. A design analysis and evaluation of inventory trend instrumentation, and test data to support design in item 1.

RESPONSE:

Reactor Vessel Head Level (RVHL)

The probe being proposed is a RADCAL Gamma Thermometer (RGT) which has many years of in-reactor service. The materials of construction and the types of measurement signals being processed for level parameters will be similar to those used in the RGT power monitors. The mechanical design of the probes will be similar to in-reactor probes currently being used. This design is described in a topical report number ScP-01 Revs. 0-4 submitted to and approved by the NRC. The operation of the RGT for water level detection is discussed in Attachment 2, "Preliminary and Simple Investigation of the Above Core Coolant Monitoring Concept."

The gamma thermometer to be installed in the reactor vessel head will serve the purpose of giving an early warning of the approach to inadequate core cooling. The sensors will be axially located to provide optimum resolution in the areas of most concern. The upper head region and the plenum region will be treated separately due to the hydraulic isolation between the two regions. In the upper head region, the stilled liquid level can be monitored while the reactor coolant pumps are running. In the plenum section, the measurement of level is not possible with the reactor coolant pumps in operation due to turbulent flow conditions. The advantages to using the gamma thermometers for level measurement in the upper head and plenum regions are as follows:

1. No density compensation is required;
2. There is a large and easily detectable signal change with a phase change of the coolant surrounding the sensor;

3. The probe is simple in design and very sturdy in construction; and
4. The signal transmission system design is straightforward.

Placing an absolute thermocouple in the probe just under the reactor head provides a unique benefit. This sensor will be designed to monitor temperature at the metal-to-liquid interface of the reactor head which is influenced by the sensible heat stored in the reactor head. This temperature measurement will provide valuable information concerning the influence of the sensible heat stored in the head on coolant conditions at the metal-to-liquid interface. Use of these temperature measurements by operators will help prevent inadvertent steam bubble formation during natural circulation cooldown and during repressurization after a small break LOCA.

Core Exit Thermocouples (CET)

No response is required for the CET monitoring system as it is not considered inventory trend instrumentation.

3. Description of tests planned and results of tests completed for evaluation, qualification, and calibration of additional instrumentation.

RESPONSE:

Reactor Vessel Head Level (RVHL)

Prior to installation of gamma thermometers as level measuring devices, it will be necessary to complete our confirmatory test program and a qualification program.

The principles of operation of a gamma thermometer as a level measuring device are well established; thus, the testing performed will be confirmatory in nature and will serve to document the plant specific nature of the device. The objectives of our test program are to demonstrate the ability of the gamma thermometer to follow level during depressurization events and to define the conditions (depressurization rates) where the gamma thermometer adequately performs this function. Preparation of our detailed program test plan will be the first step. The test plan will specify all elements necessary to satisfy the objectives of the program. The tests are expected to confirm the unambiguity of the indication of liquid/steam phase changes above the core.

Depressurization tests will be conducted in an instrumented blowdown loop to confirm the ability of the gamma thermometer to follow level. A variety of depressurization rates will be used in the tests to determine the bounds of operation of the gamma thermometer as a level measurement device.

An important element in the program will be the documentation of the results of testing. The documentation will be reviewed in detail and an analysis of the test results will be performed to determine that the objectives of the test program were satisfied.

To satisfy the qualification program, environmental and seismic qualification will be addressed. For the gamma thermometer, environmental qualification will be documented by design and operational experience. These probes have had many years of in-reactor service as a power measuring device. Since the construction of a probe for level detection is similar to that of probes used for power monitoring, we feel sufficient information exists for qualification. Quality assurance during the manufacture of the gamma thermometer will ensure that the integrity of the pressure boundary is maintained. Since the probe is essentially a solid rod, seismic qualification will be achieved by analysis. The simplicity of design will allow the use of straightforward analytical techniques.

The signal transmission and processing systems up to and including the isolators will be comprised of components which are currently available and qualified. No electronic systems are to be located inside the containment building, thus simplifying the environmental qualification required.

Core Exit Thermocouples (CET)

Post installation checkout and calibration procedures for the CET monitoring system have not been developed at this time. These will be provided at a later date.

Environmental and seismic qualification of all components of the CET monitoring system with exception of the SPDS computer and its input cables will be demonstrated in accordance with IEEE 323-1974 and 344-1975 where the selected vendor has not yet qualified the equipment. The qualification will be proven by type testing, operating experience, analysis, or any combination of these methods. However, previously qualified equipment may be used where engineering analysis proves that the documented qualification parameters for the equipment meet or exceed the worst case DBE conditions expected at the installed locations.

In-Core Monitor (ICM)

Much of the testing and qualification discussed above is applicable to the use of a gamma thermometer as an in-core monitor. To achieve this, the test program will confirm the ability of the device to accurately monitor reactor coolant temperature and heat transfer coefficients as well as development of a correlation of fuel clad temperature for fuel rods surrounding the probe. During this phase of the program, the probe will be inserted in an instrumented test assembly. Appropriate data will be collected and reviewed to establish these correlations and further verified by use of standard thermal-hydraulic codes.

Seismic and environmental qualification will be achieved consistent with the program outlined for reactor vessel head level.

4. Provide a table or description covering the evaluation of conformance with NUREG-0737: II.F.2, Attachment 1, and Appendix B (to be reviewed on a plant specific basis).

RESPONSE:

Sub-cooled Margin Monitor (SMM)

This item is addressed in our letter dated January 18, 1980 (ØCANØ18Ø22).

Reactor Vessel Head Level (RVHL) (II.F.2, Appendix B Format)

1. Environmental Qualification - The gamma thermometer probes, signal transmission system and signal processing system up to and including the isolators will be seismically and environmentally qualified as discussed above. The display of reactor vessel level information will be provided on the SPDS computer. Although not qualified, the computer has redundant processing units which provide a high degree of reliability for the mild environment in which it is located.

2. Single Failure Analysis - For vessel head level measurement, two gamma thermometer probes will replace two in-core instrument assemblies. Electrically, the two probes are separate and two channels of diverse cable routing will be maintained up to the class 1E isolation devices. From the isolation devices, both channels are input to a common display, the SPDS computer. The SPDS has been designed to approach 99% availability.

3. Class 1E Power Source - All portions of the system will be provided with class 1E power with the exception of the SPDS computer. This computer has its own inverter power supply and is battery backed for reliability.

4. Availability Prior to an Accident - The reactor vessel head level system will be available prior to an accident. Because the system is composed of two redundant channels, one channel may temporarily be removed from service for surveillance, calibration or maintenance while the other channel remains in service.

5. Quality Assurance - AP&L's quality assurance program as documented in the Quality Assurance Manual, APL-TOP-1A, Revision 5, complies with the referenced Regulatory Guides with the exception of 1.144, 1.146 and 1.58. We have committed to 1.146 and 1.58 in our letter to Mr. Eisenhut dated July 27, 1981 (ØCANØ7811Ø), and we are committed to ANSI N45.2.12 Draft 4, Revision 2 (1/1/76) in lieu of Regulatory Guide 1.144.

6. Continuous Indications - The Reactor Vessel Head Level information will be continuously provided to the SPDS computer along with other inputs. Any information provided to the computer is available to be instantly displayed in a human factored color graphics console at the request of an operator.

7. Recording of Instrument Outputs - Recording of reactor vessel head level information will be performed using the trending capabilities of the SPDS computer. The trend information will be stored by the computer and will be available for display upon demand.

8. Identification of Instruments - Since the SPDS computer is being used as a display system, no discrete instruments will be located in the control room for reactor vessel level monitoring. The SPDS is widely recognized as being useful for monitoring and assessing accident conditions.

9. Isolation - The gamma thermometer probes, signal transmission system, and signal processing system will be class 1E. Where interface with non-class 1E systems is necessary, qualified isolation will be provided.

Core Exit Thermocouples (CET)

The design and qualification criteria for the core exit thermocouples are discussed below in accordance with the format of II.F.2, Attachment 1.

1. Figure 2 shows the locations of the in-core instrument assemblies. The core exit thermocouple is part of the in-core instrument.

2.a. The SPDS computer will be used as the primary display. The color graphic capabilities will be used to provide a core map with core exit thermocouple temperatures.

b. The core exit thermocouples have a range of 0°F-2300°F. The readouts will conform to this range.

c. Readings that are out of range high or low bring in an alarm on the alarm CRT of the computer. This alerts the operator of possible instrument failures. Out of range readings are rejected by the computer prior to calculating the average of the five highest.

d. The final arrangement of the ICC instrumentation readouts will not be available until the Control Room Design Review is completed.

3. The backup display will be a single indicator which has input signals from at least 16 core exit thermocouples. Individual thermocouples are to be selected manually. The operability will be checked by periodic surveillance and calibration. The range of the display will be 0°F-2300°F.

4. Use of the primary display will be based on the EOPs for ICC. The backup display will be used when the primary is unavailable. The primary display will be designed to provide the core exit temperature information that the operator needs to cope with ICC. This information should be called for by the EOP at the time it is required.

   Training will consist of procedure training specifying what indications to monitor and what actions to take based on the indications. CETs should always be available to provide backup indication for reactor outlet RTDs (hot leg).

The remainder of the items in II.F.2, Attachment 1 are also covered in II.F.2, Appendix B. To further discuss the design and qualification criteria of the core exit thermocouples, the response is arranged in Appendix B format.

1. Environmental Qualification - See response to item 3 of Appendix A. With the exception of the CETs and in-containment connectors and cables, all parts of the CET monitoring system are accessible for maintenance during normal or accident conditions.

2. Single Failure Analysis - The proposed 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 a common display (SPDS). The SPDS has been designed to approach 99% availability. The sixteen (16) CET inputs to the backup display will be derived from one of the channels.

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

4. Availability Prior to an Accident - It is intended that the CET information will be available continuously. Because of the redundant channel design, a channel can be out of service for calibration or maintenance for short periods of time while the other channel remains in service.

5. Quality Assurance - AP&L's quality assurance program as documented in the Quality Assurance Manual, APL-TOP-1A, Revision 5, complies with the referenced Regulatory Guides with the exception of 1.144, 1.146 and 1.58. We have committed to 1.146 and 1.58 in our letter to Mr. Eisenhut dated July 27, 1981 (ØCANØ78110), and we are committed to ANSI N45.2.12 Draft 4, Revision 2 (1/1/76) in lieu of Regulatory Guide 1.144.

6. Continuous Indication - The CET temperature information for the primary display will be available via an SPDS computer display which an operator can select and display continuously upon demand.

The operator must also manually select the desired CET location to monitor via the backup display. As all CETs will monitor temperature over the same range, there will be no gaps in the measurement.

7. Recording of Instrument Outputs - Recording of CET temperature information will be performed for the primary display only using the trending capabilities of the SPDS computer. The trend information will be stored by the computer and will be available for display upon demand.

8. Identification of Instruments - The SPDS computer is being used as a display system. The SPDS is widely recognized as being useful for monitoring and assessing accident conditions. The backup display, however, will be clearly identified on the control board regarding its use as an accident monitoring device.

9. Isolation - Refer to the response to item 1(c) of Appendix A for a description of the electrical isolation and physical separation aspects of this design.

<u>In-Core Monitor (ICM)</u>

The design and qualification criteria for the in-core monitoring system are discussed below in accordance with the format of II.F.2, Attachment 1.

1. Figure 2 shows the locations of existing in-core instruments. Two of the in-core instruments will be removed and replaced with gamma thermometer probes.

2.a. The ICM display will be provided on the SPDS computer. The computer's color graphic capabilities will be utilized to display the sensor's locations at different elevations in the reactor.

b,c,d. Information on the range of the readouts, the alarm system and the arrangement of the ICC instrumentation will be defined during the final detailed design and testing. Human factors consideration will be appropriately incorporated in the design.

3. It is not proposed to provide a backup display system for the ICM.

4. Emergency Operating Procedures (EOPs) will be revised to integrate the use of the in-core monitor display. The operators will be trained on the revised procedures.

The remainder of the items II.F.2, Attachment 1 are also addressed in II.F.2, Appendix B. To further discuss the design and qualification criteria of the in-core monitoring system, the response is arranged in Appendix B format.

1. Environmental Qualification - The gamma thermometer probes, signal transmission system and signal processing system will be seismically and environmentally qualified. The display is provided via the SPDS computer which is not qualified. However, the computer has been designed to approach an availability of 99%.

2. Single Failure Analysis - For in-core monitoring, two gamma thermometer probes will replace two in-core instrument assemblies. Electrically, the two probes are separate and two channels of diverse cable routing will be maintained up to the class 1E isolation devices. From the isolation devices, both channels are input to a common display, the SPDS computer.

3. Class 1E Power Source - The signal processing system display will have a class 1E power source. The SPDS computer display is not a class 1E system, thus it does not have a class 1E power source. The computer is, however, backed by a battery system and an inverter provides it with an uninterruptible power supply.

4. Availability Prior to an Accident - The in-core monitoring system will be available prior to an accident. Because the system is composed of two redundant channels, one channel may be temporarily removed from service for surveillance, calibration or maintenance while the other channel remains in service.

5. Quality Assurance - AP&L's quality assurance program as documented in the Quality Assurance Manual, APL-TOP-1A, Revision 5, complies with the referenced Regulatory Guides with the exception of 1.144, 1.146 and 1.58. We have committed to 1.146 and 1.58 in our letter to Mr. Eisenhut dated July 27, 1981 (ØCANØ7811Ø), and we are committed to ANSI N45.2.12 Draft 4, Revision 2 (1/1/76) in lieu of Regulatory Guide 1.144.

6. Continuous Indication - The ICM information will be continuously provided to the SPDS computer along with other inputs. Any information provided to the computer is available to be instantly displayed in a human factored color graphics console at the request of an operator.

7. Recording of Instrument Outputs - Recording of in-core information will be performed using the trending capabilities of the SPDS computer. The trend information will be stored by the computer and will be available for display upon demand.

8. Identification of Instruments - The display is the SPDS computer which is widely recognized as being useful for monitoring and assessing accident conditions.

9. Isolation - The gamma thermometer probes, signal transmission system and signal processing system will be class 1E. These will be isolated from the non-class 1E SPDS computer.

5. Describe computer, software and display functions associated with ICC monitoring in the plant.

RESPONSE:

Sub-cooled Margin Monitor (SMM)

The details of the SMM system were provided in our letter dated January 18, 1980, (ØCANØ18Ø22).

Reactor Vessel Head Level (RVHL)

The signals from the above core RGTs will be transmitted to the SPDS computer for processing and displaying on color graphic CRTs which currently exist in the ANO-2 Control Room. Display formats will be developed to provide unambiguous, easy to interpret indication of approach to ICC above the core. The computer will clearly indicate on the display screen when certain portions of the indication may not be valid. For example, the outlet plenum area between the top of the fuel and the outlet nozzle region will be inhibited or denoted on the display when the Reactor Coolant Pumps (RCPs) are running to notify the operators that the level indication in that region may be invalid.

Since the SPDS is installed, the data acquisition software currently exists. Some further software development will be required to provide signal processing and graphic displays for the RVHL. Once developed, the display formats and the operating procedures for utilization of the displays will be evaluted in the Control Room Design Review (CRDR) program.

Core Exit Thermocouple (CET)/In-Core Monitor (ICM)

The signals from the in-core RGTs and the CETs will be transmitted to the SPDS computer for processing and display on color graphic CRTs which currently exist in the ANO-2 Control Room. Display formats will be developed to provide unambiguous, easy to interpret indication of ICC in the core.

Since the SPDS computer is installed, the data acquisition software currently exists. Some further software development will be required to provide signal processing and to produce the graphic displays. Once developed, the display formats and the operating procedures for utilization of the displays will be evaluted in the Control Room Design Review (CRDR) program.

6. Provide a proposed schedule for installation, testing and calibration and implementation of any proposed new instrumentation or information displays.

RESPONSE:

Figure 4 is the projected schedule for the installation and implementation of the new components of the ICC instrumentation system. The dates in the schedule are contingent upon AP&L budget approval of this project by July 1, 1983. As shown in the figure, the scheduled installation date for the Rector Vessel Head Level (RVHL)/In-Core

Monitoring (ICM) instrumentation is during the fourth refueling outage (currently scheduled from 9/15/85 to 12/15/85). This schedule is also contingent upon NRC review and approval at the key test program milestones.

Furthermore, the Core Exit Thermocouple (CET) instrumentation system is projected to be upgraded as previously described during the fifth refueling outage. All displays, signal processing equipment, cable, and connectors should be installed prior to the end of the outage. The EOPs will be revised to reflect the use of the additional ICC display information and operators will be trained prior to implementation of the system.

7. Describe guidelines for use of reactor coolant inventory tracking system, and analyses used to develop procedures.

RESPONSE:

Guidelines for the use of the reactor coolant inventory tracking system are not currently developed. These guidelines will be developed from analyses performed in conjunction with the testing program for the inventory tracking system.

8. Operator instructions in emergency operating procedures for ICC and how these procedures will be modified when final monitoring system is implemented.

RESPONSE:

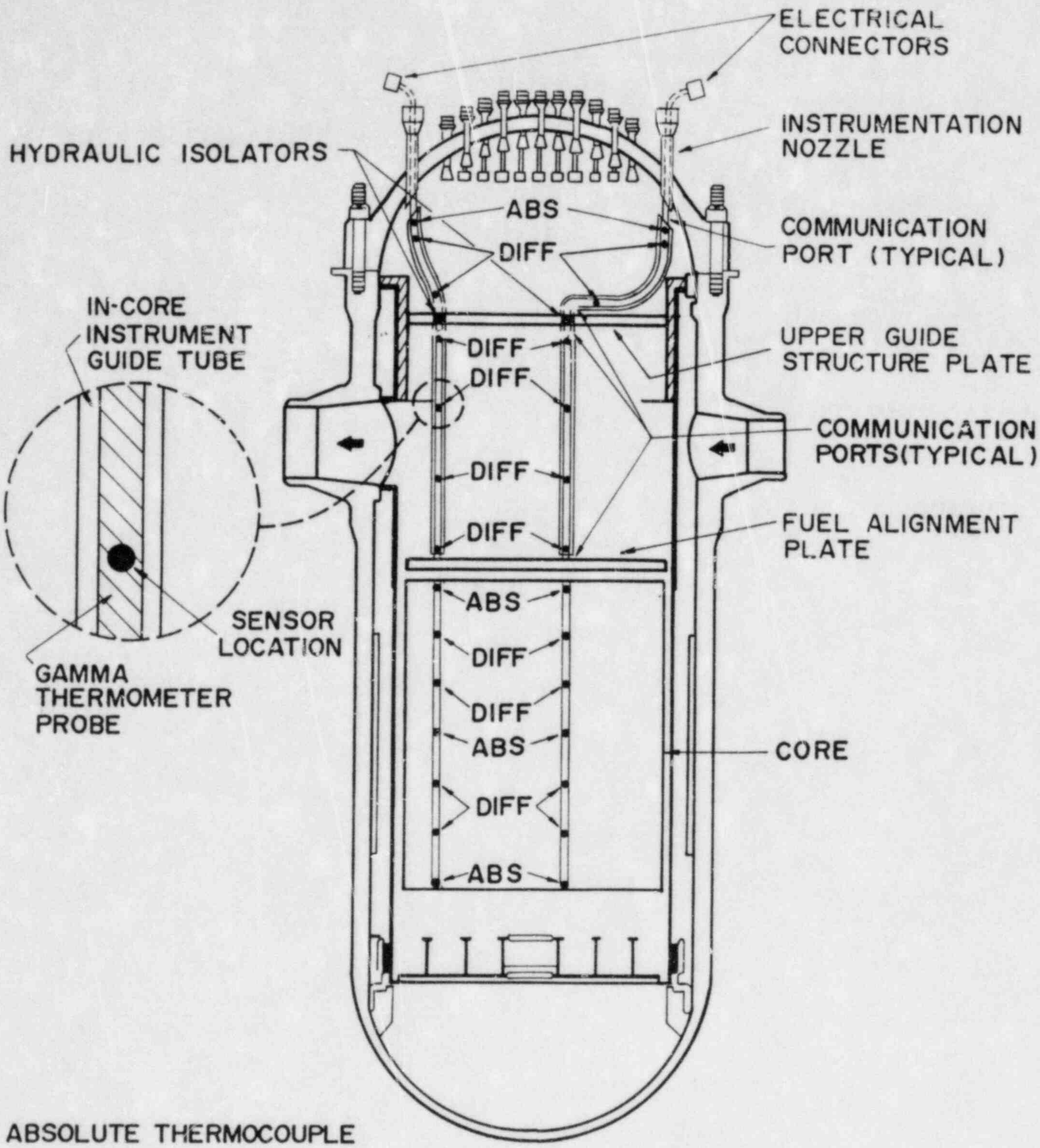
Reactor coolant system pressure and temperature increasing in a saturated condition is an indication insufficient core cooling exists. When this occurs, operations are instructed to open the pressurizer ECCS valves to lower RCS pressure and provide greater high pressure injection flow. Upon implementation of the final monitoring system, changes will be made to procedures based on guidelines discussed in item 7 (above).

9. Provide a schedule for additional submittals required.

RESPONSE:

Two additional submittals are planned at key milestones shown in the Appendix A, item 6 discussion. These are the test program plan and the final test report. NRC review and approval of these submittals will be required for AP&L's continuation of the effort to implement the RGT use for ICC monitoring.

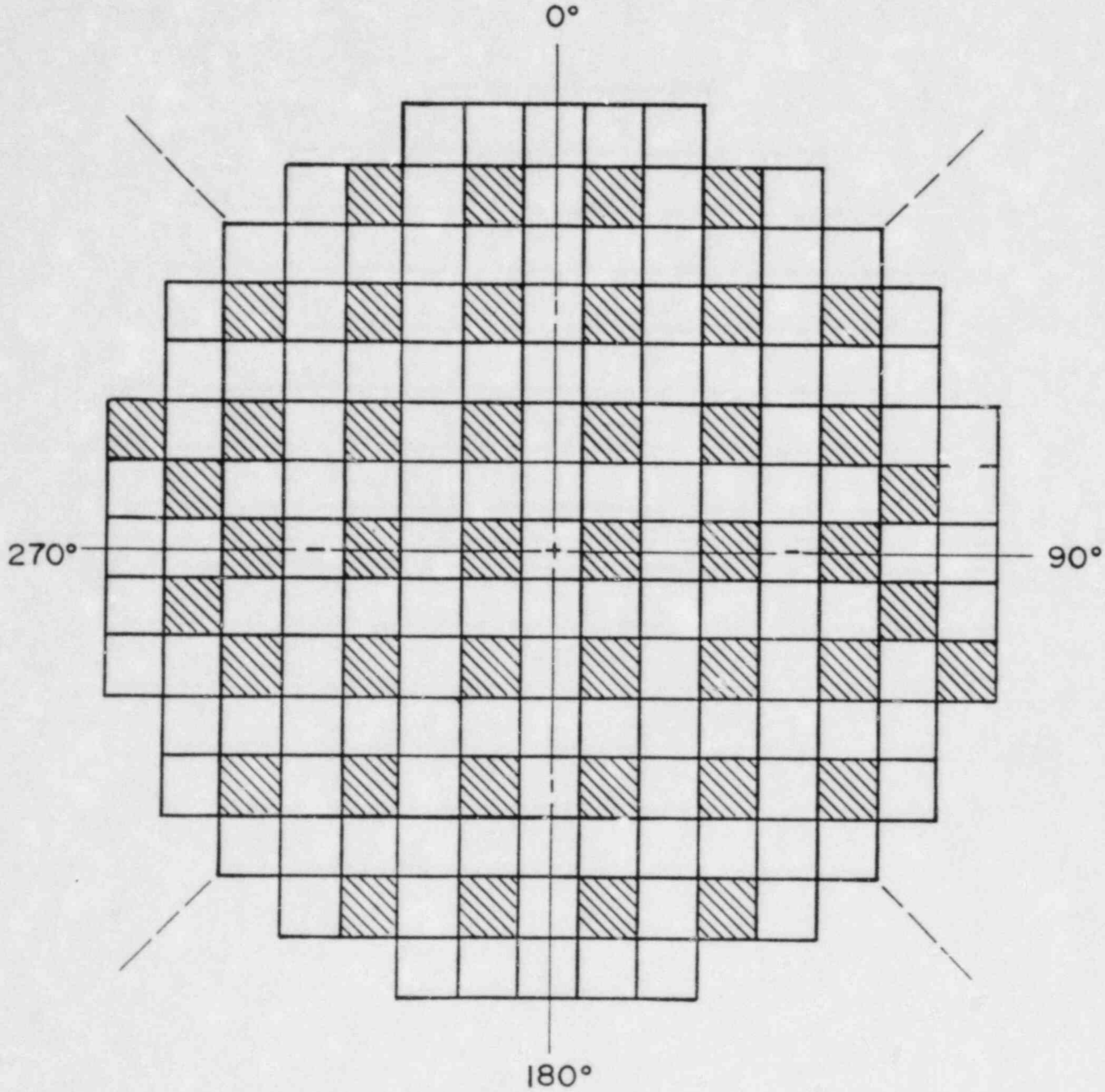
FIGURE 1



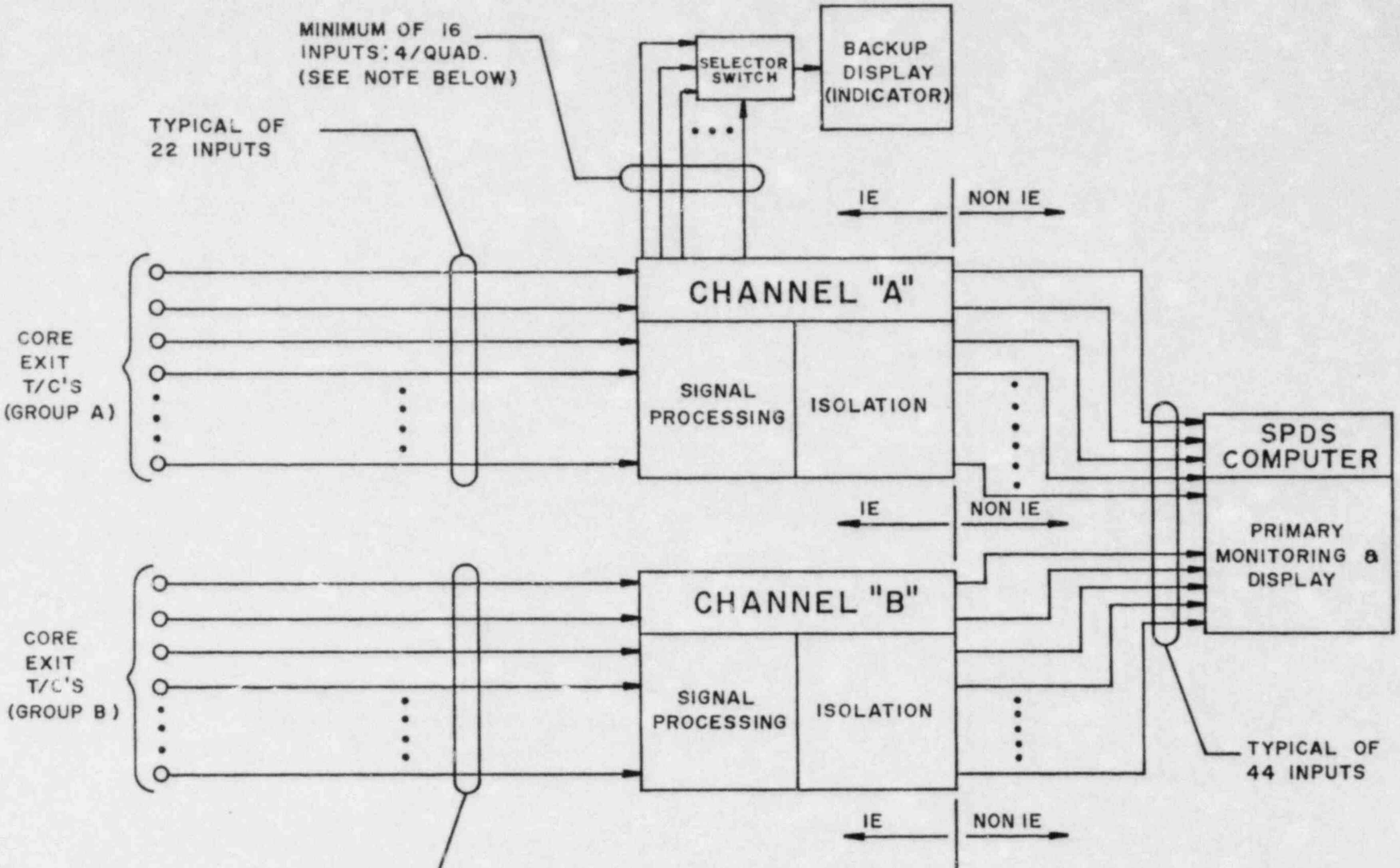
ABS - ABSOLUTE THERMOCOUPLE
DIFF - DIFFERENCE THERMOCOUPLE

UNIT- 2 REACTOR VESSEL

FIGURE 2



ANO-2 INCORE DETECTOR LOCATIONS



NOTES:

THE BACKUP DISPLAY INPUTS ARE DERIVED IN THE SIGNAL PROCESSING LOOP UPSTREAM OF THE ISOLATOR. ALTHOUGH THEY ARE SHOWN AS PART OF CHANNEL A, THEY MAY OPTIONALLY COME FROM CHANNEL B.

ANO-2 CORE EXIT THERMOCOUPLE (CET) MONITORING SYSTEM FIGURE 3

ANO-2 ICC INSTRUMENTATION SCHEDULE

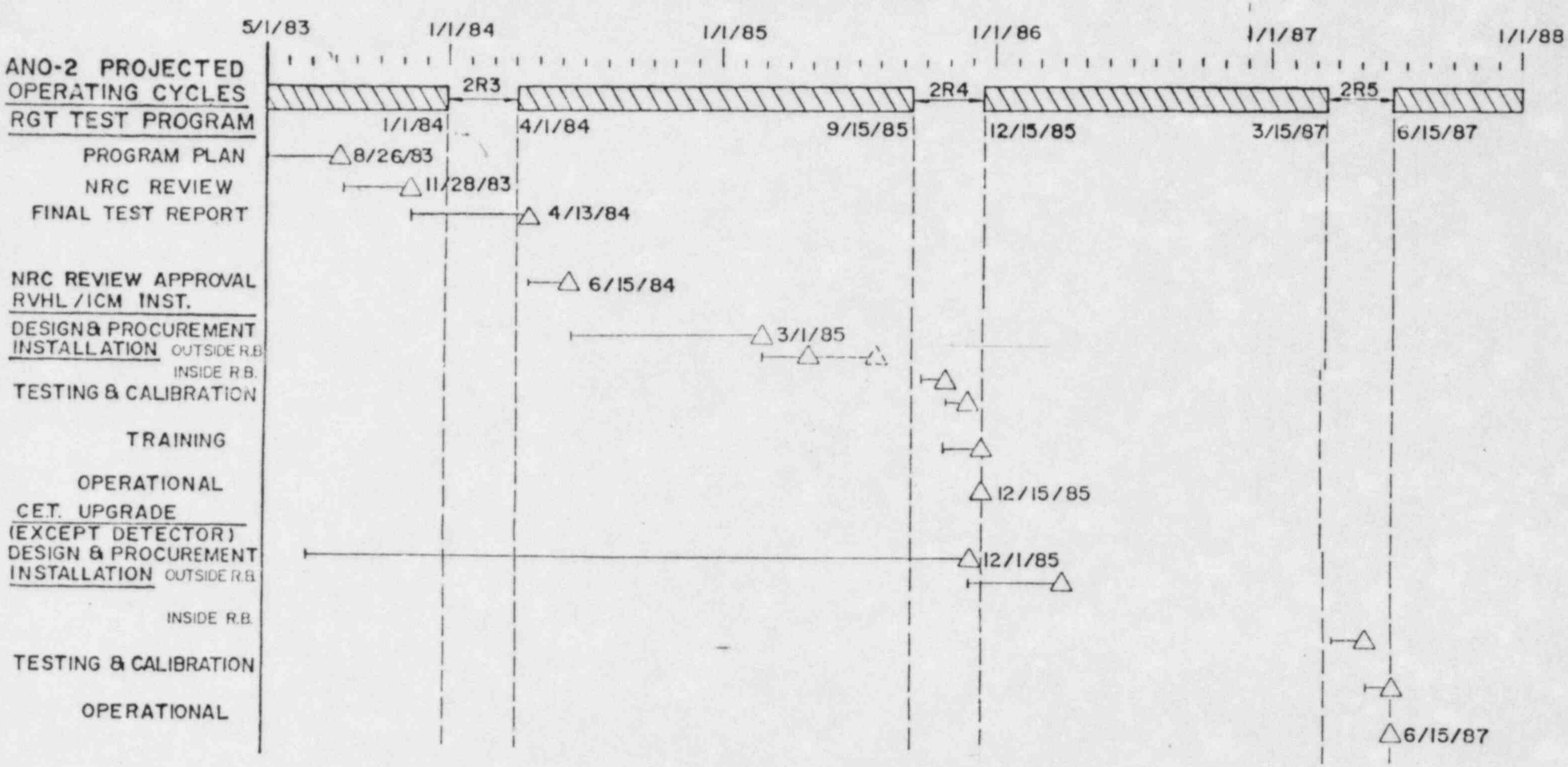


FIGURE 4

ATTACHMENT 2

PRELIMINARY AND SIMPLE EXPERIMENTAL INVESTIGATIONS
OF THE ABOVE-CORE COOLANT MONITORING CONCEPT

1. GENERAL

Within the scope of this study some simple experiments were carried out to get answers to question like:

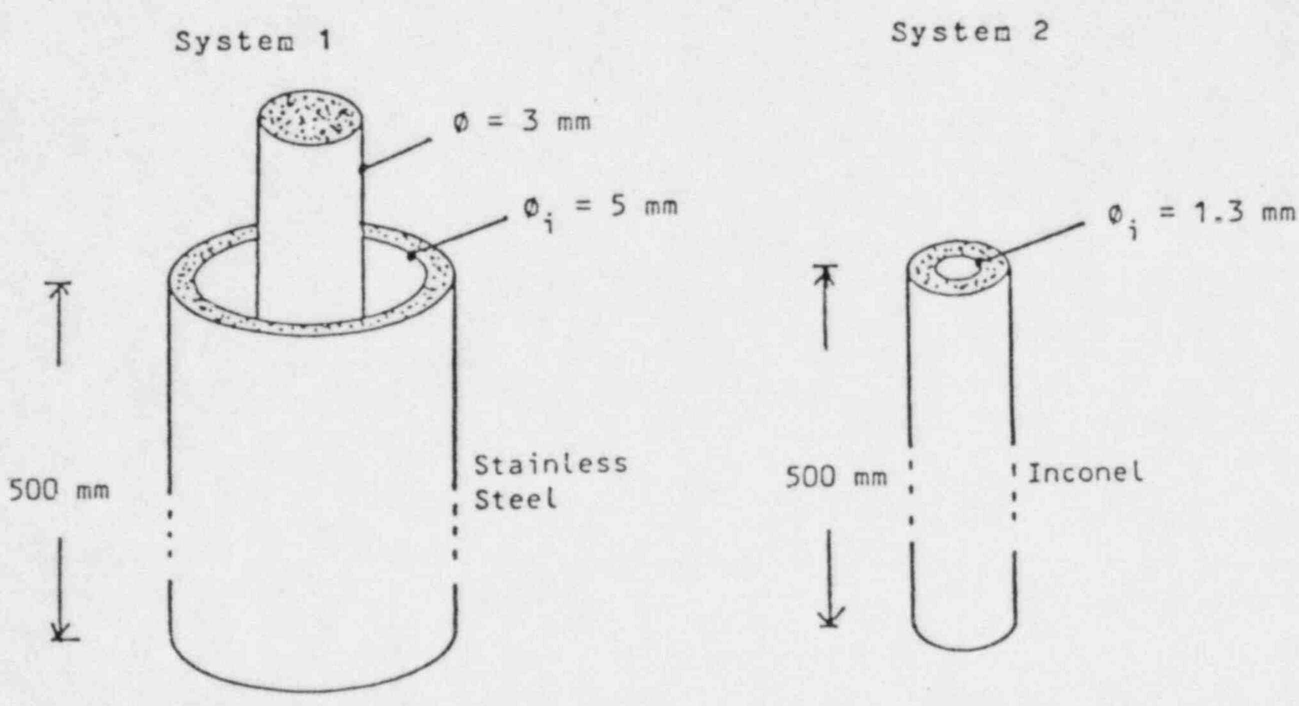
-- how quickly will a tube system as that consisting of a thermocouple guide tube and an RGT rod drain?

-- how quickly and how much does the sensor signal increase when the sensor is being uncovered?

2. DRAINAGE TESTS

System Used

In these tests two systems were investigated. System 1 consists of a tube corresponding to thermocouple guide tube with inside diameter (5mm) with a solid rod inside having a diameter identical to the RGTrod (3.0 mm). System 2 consists of a single tube having a hydraulic diameter somewhat less than System 1 (i.e., 1.3mm versus 2.0mm).



The drainage tests were carried out at two different temperatures, i.e., 15°C and 56°C to investigate temperature effects on drainage rates.

Results

The results are summarized in the table below:

	15°C		56°C	
	System 1	System 2	System 1	System 2
$\bar{\tau}$ (sec)	1.20	1.08	0.79	0.725
std.dev. ± (sec)	0.09	0.05	0.06	0.07
no. of tests	26	25	13	12

The test shows that the 0.5m drainage length empties quickly. As expected System 2 has slightly smaller drainage rate compared to System 1 due to larger hydraulic diameter.

The drainage rate decreases with increasing temperature due to reduced viscosity and surface tension. An appreciable decrease is observed over such a small temperature range as 40°C.

At PWR conditions the drainage rate would have been further increased although the viscosity and surface tension of water are not changing that fast with temperature in these higher temperature ranges.

Expected Drainage Time

In order to get a better understanding of the observed drainage times, an ideal case can easily be investigated where there is assumed no friction losses in the tube and no outlet losses.

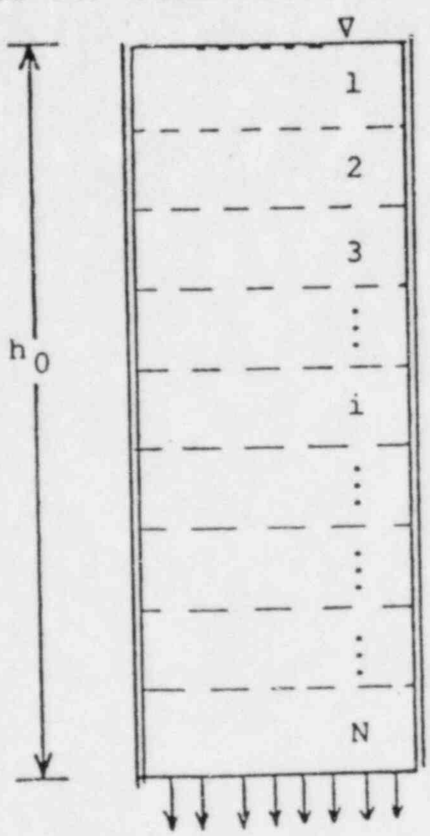
For such a simple case the gravity head is directly transferred into kinetic energy and the Bernoulli equation reads:

$$h = \frac{V^2}{2g}$$

or

$$V = \sqrt{2gh}$$

The minimum time it would take to drain a water column of height h_0 can be calculated numerically by dividing the height into N sections and calculating the drainage time for each section.



The drainage time for section i is:

$$\tau_i = \frac{h_0}{N} \frac{1}{\sqrt{2g\left(h_0 - \frac{(i-1)h_0}{N}\right)}}$$

and total drainage time:

$$\tau = \sum_{i=1}^{N} \frac{h_0}{N} \frac{1}{\sqrt{2g\left(h_0 - \frac{(i-1)h_0}{N}\right)}}$$

For the actual case the following data were used:

$h_o = 0.5$ m and $N = 5$

This gives for drainage time:

$_1 = 0.07$ sec.

$_2 = 0.08$ sec.

$_3 = 0.09$ sec.

$_4 = 0.11$ sec.

$_5 = 0.15$ sec.

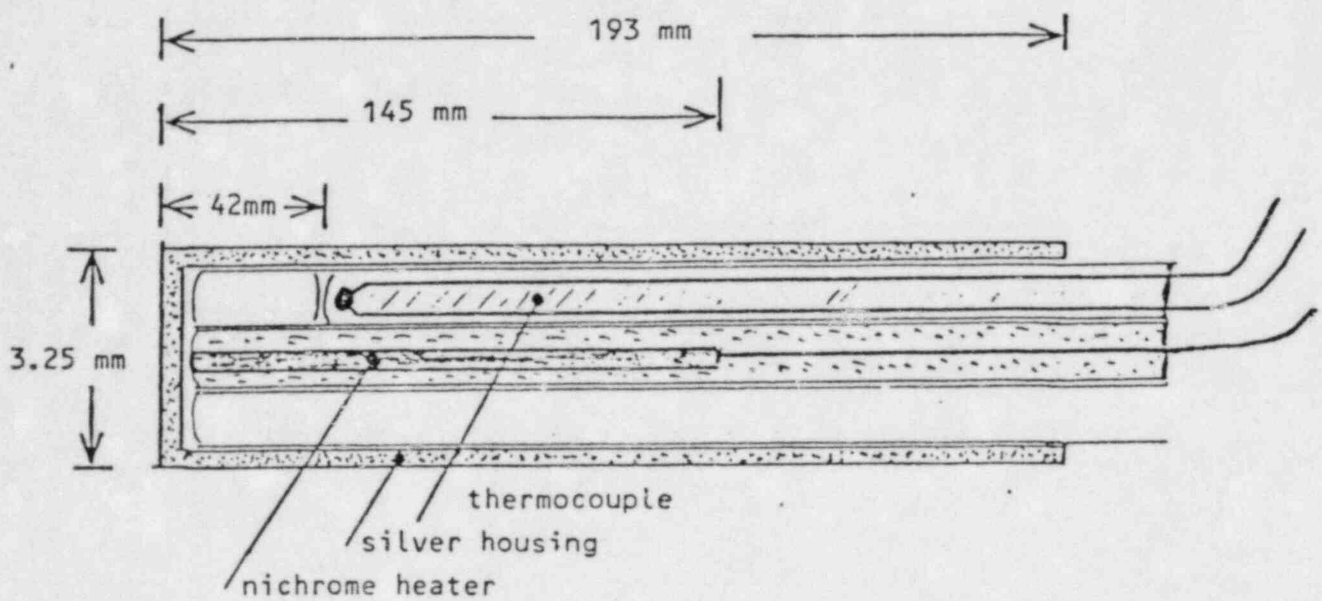
$\tau = 0.50$ sec.

The calculated drainage time checks fairly well with that observed for 56°C. In this case the friction is low and the conditions fairly close to the ideal situation. In the ideal calculation no allowance has been made for initial acceleration of the water. It is therefore concluded that the water drainage occurs as expected with no peculiar "hang-up" of water due to capillary forces.

3. TESTS WITH ABOVE CORE RGT ROD

RGT Sensor Used

From earlier investigations Scandpower had available an RGT sensor that partially could mock-up the Above Core RGT rod. The sensor (see sketch) consisted of a thermocouple array of 6 1mm thermocouple cables surrounding a central 1mm heater cable. The array was contained in a silver housing tube of outer diameter 3.25mm and length 193mm.



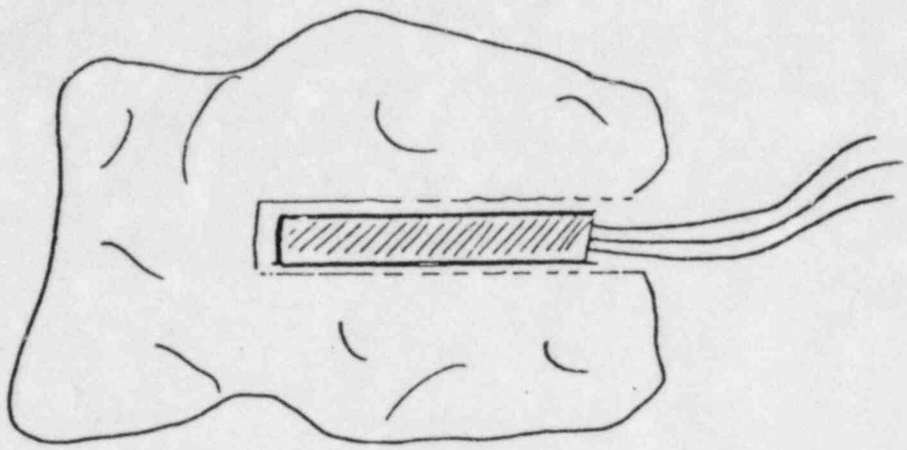
The heater cable had a heated length of 145mm in the lower end of the pack. One of the thermocouples was a standard thermocouple having its tip located 42mm from the lower end of the pack.

Although difference thermocouples are used in the proposed Above Core RGT rod, the experimental set-up can simulate such a rod as the tip location of the standard thermocouple is heated by the heater cable while its reference point (connection to copper leads) stays cold.

Measurements Carried Out

Thermally Insulated Cable Pack

In order to establish a reference the cable pack was insulated in insulation material and a heating power of 20W applied to the heater cable.



The response of the standard thermocouple is shown in Figure 1. It is seen that an initial temperature rise of about 2.72 °C/sec is found. When the temperature increases, heat is lost through the thermocouple wires sticking out of the insulation. This is clearly seen from the cooling taking place when the heating power is switched off.

For comparison measurements were made with the cable pack in still air. As seen from Figure 1 there is not much difference from the insulated case.

Expected Temperature Rise

The measured temperature rise can be checked by a very simple calculation. Using the dimensions of the cable

pack and assuming it all steel, it is found:

Volume: $\left(\frac{3.25 \times 10^{-1}}{2}\right)^2 \times 3.14 \times 19.3 = 1.6\ cm^3$

Mass: $1.6\ cm^3 \times 7.9\ g/cm^3 = 12.64\ g$

Heat capacity: $12.64\ g \times 0.5\ ws/g^oC = 6.325\ ws/g^oC$

Applied heat: $RI^2 = 2.8 \times 2.7^2 = 20.4\ W$

Temperature rise: $\frac{20.4}{6.325} = 3.2\ ^oC/s$

The error by assuming Al_2O_3 in the cables replaced by steel is not large as the product density x specific heat is very much identical for the two materials. Silver and steel are also similar from density and heat capacity point of view.

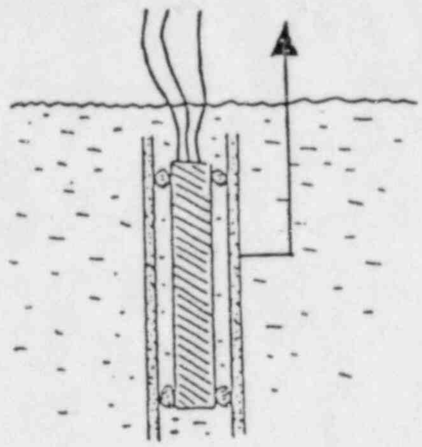
The calculated temperature rise is higher than that experimentally observed, i.e., 3.2 vs 2.7 ^oC/sec. The reason is probably that the cable pack has a larger "efficient" size than assumed in the calculations as also part of the cables sticking out from the insulation are being heated.

Measurements with Water

The cable pack was installed in a guide tube of inside diameter 5.0 mm and were both inserted into water of temperature 76^{o}C. The heater current was switched on and signal stabilized. Then the tube was quickly

pulled out from the water. The temperature response is shown in Figure 4. It is seen that initially there is a small drop in temperature as air of 15°C fills up the space of the 76°C water draining out. Then after 2 secs the temperature starts increasing.

The temperature rise is almost identical to that observed for the insulated cable pack (i.e., 2.6 °C/sec vs. 2.7 °C/sec). This clearly indicates that no water remains inside to be heated up.



It is clearly seen that a temperature increase of about 70-80°C takes place. The real response is, however, about 130°C as the sensor started out at 76°C and is moved out into air of 15-20°C. The reference junction is at air temperature, and without the heater, the sensor temperature would have dropped 50°C relative to the reference junction when pulled out of the water. With the heater on it ends up 70°C above the reference temperature.

A temperature increase of only 130°C is too low when the annular gap is air filled. Simple calcualtions indicate temperatures up in the range 300°C. The reason for the relative low temperature increase can be that the cable pack is not properly insulated from the guide tube and further can air streaming around the sensor reduce the temperature rise.

These postulates were checked with the cable pack placed horizontally so that air streams through the gap are minimized. The cable pack was tested insulated from the guide tube and directly inserted in the guide tube.

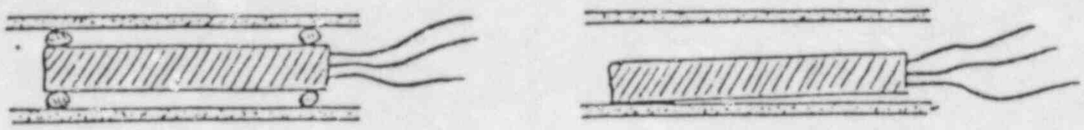
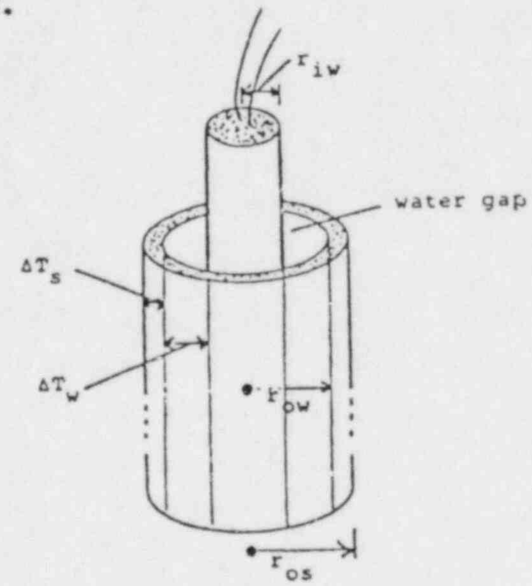


Figure 3 shows that the temperature increase is much higher this time when air streaming is diminished. There is not much difference, however, between the insulated and non-insulated case clearly indicating that inadequate insulation was used.

Steady State Signal

From Figure 2 it is seen that when the heater current is switched off after reinsertion of the tube system in water, the temperature drops and stabilizes at a 12°C lower temperature. This means that the steady state signal during normal operation with heater cable is about 12°C.



The temperature drop from the cable pack out to the bulk of water can be calculated assuming pure conduction and no temperature drop on the tube surfaces.

The temperature drop is then given by:

$$\Delta T = \Delta T_w + \Delta T_s = \frac{q}{2\pi} \left(\frac{\ln \frac{r_{ow}}{r_{os}}}{k_w} + \frac{\ln \frac{r_{os}}{r_{ow}}}{k_s} \right)$$

where

q = linear heat rate = $\frac{20.4}{14.5}$ W/cm = 1.40 W/cm

k_w = heat conductivity water = $66 \cdot 10^{-4}$ W/cm°C

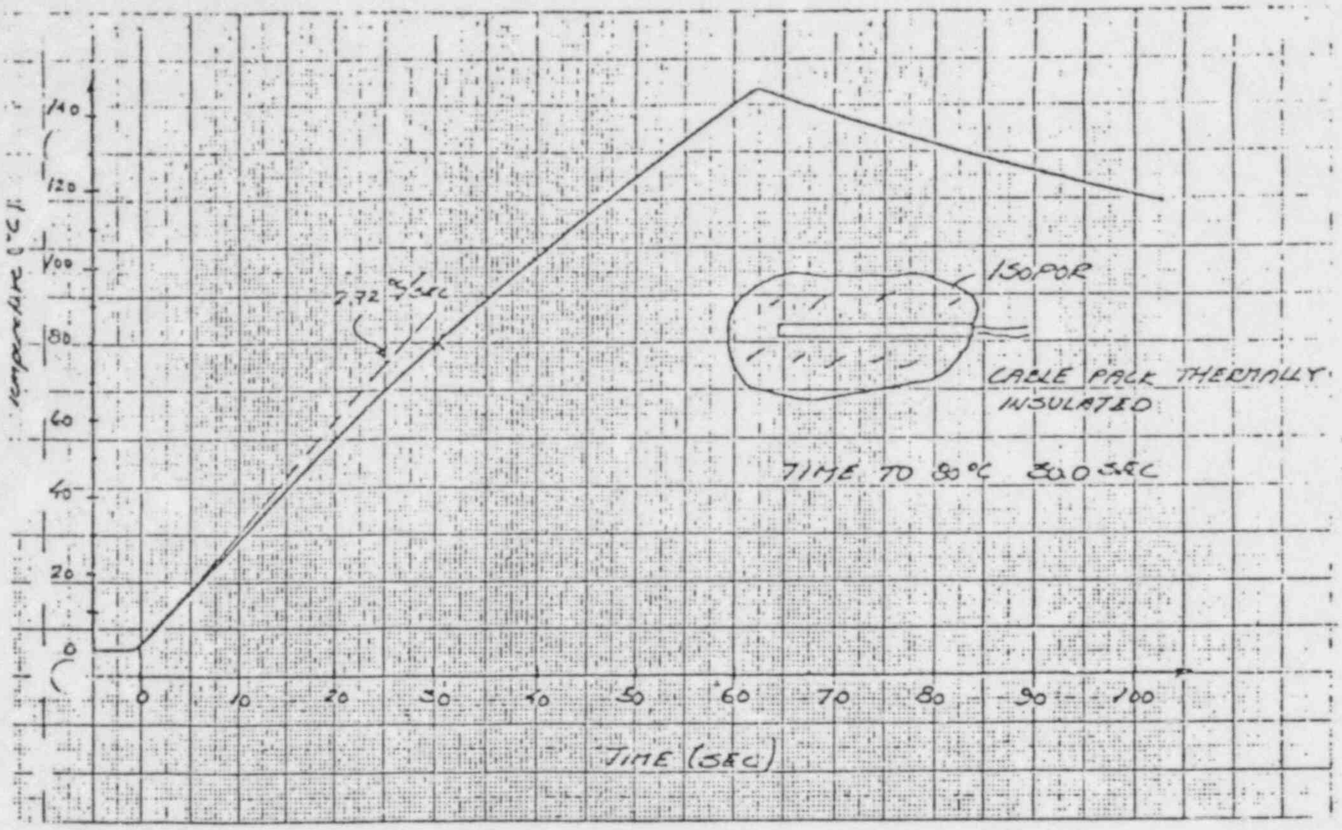
k_s = heat conductivity steel = $15 \cdot 10^{-2}$ W/cm°C

r_{iw} = 3.25 mm r_{ow} = 5mm r_{os} = 7.0mm

$$\Delta T = \frac{1.40}{6.28} \left(\frac{\ln \frac{5.0}{3.25}}{66 \cdot 10^{-4}} + \frac{\ln \frac{7.0}{5.0}}{0.15} \right) {}^{\circ}C =$$

$$= (14.55 + 0.5) = \underline{\underline{15^{\circ}C}}$$

This calculated temperature drop compares fairly well with the measured one.


TIME (SEC)
7.72 °/SEC
ISOPOR
CABLE PACK THERMALLY INSULATED
TIME TO 80°C 30.0 SEC

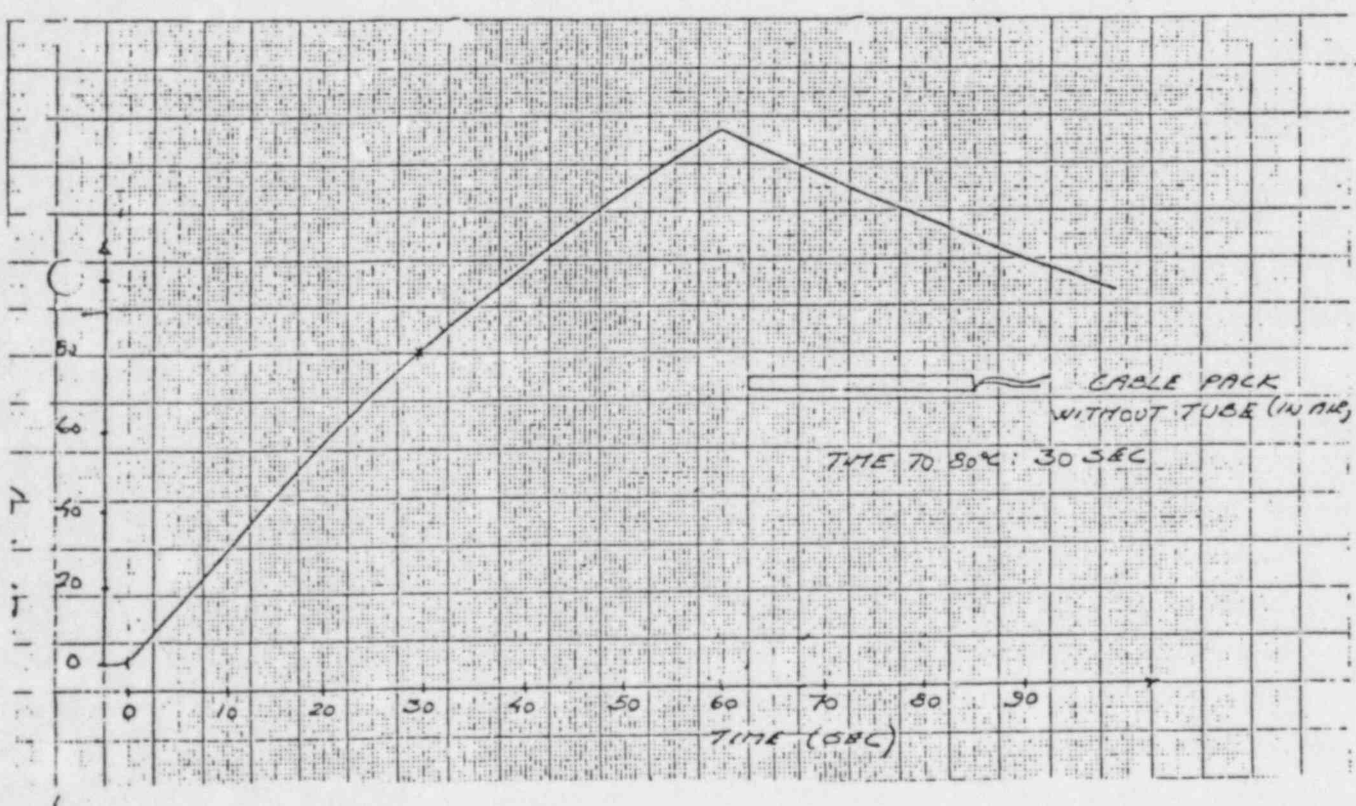
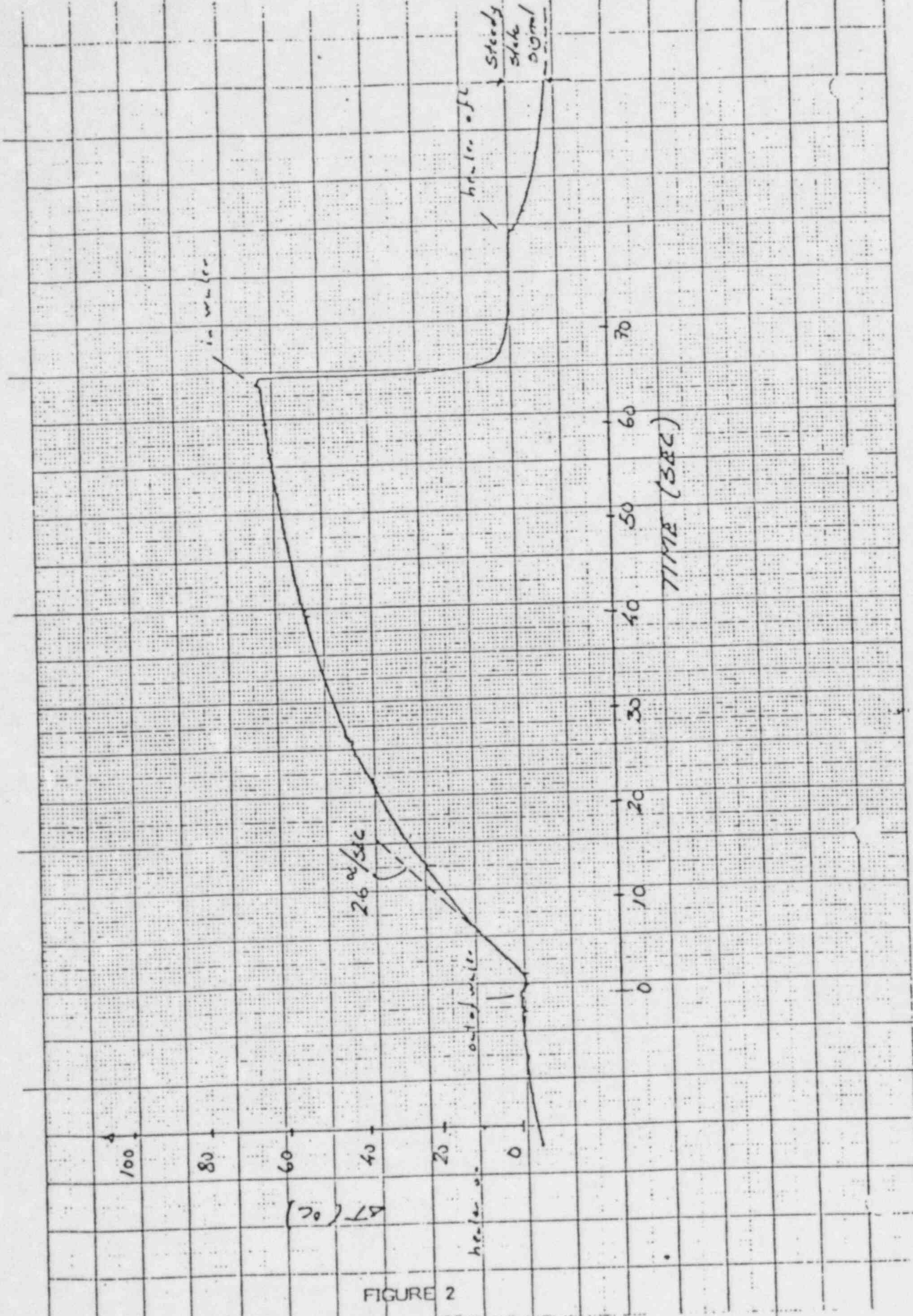
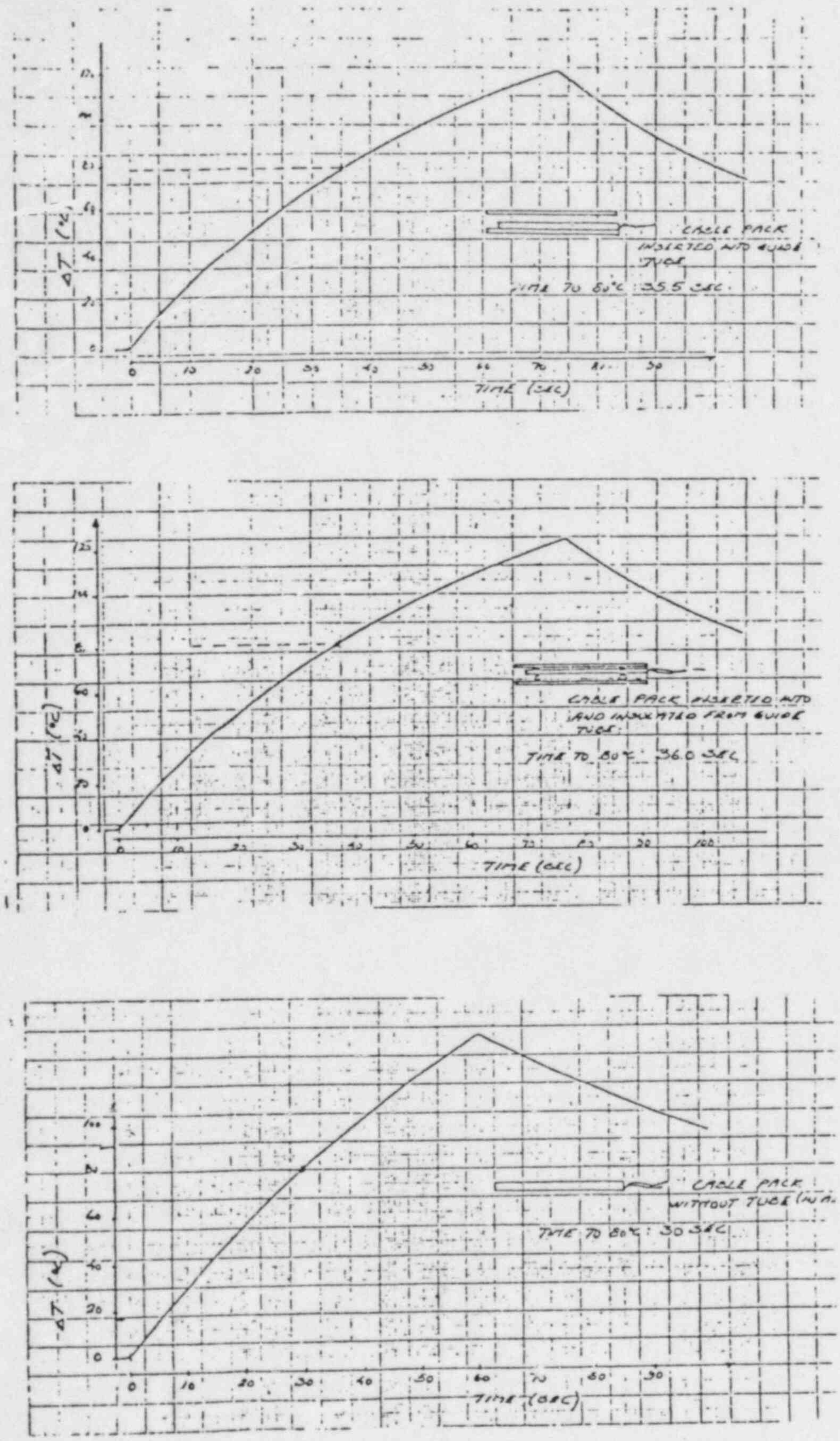

CABLE PACK WITHOUT TUBE (IN AIR)
TIME TO 80°C : 30 SEC
TIME (SEC)

FIGURE 1



TIME (SEC)
0
10
20
30
40
50
60
70
ΔT (°C)
0
20
40
60
80
100
26 °C/SEC
steady state signal

FIGURE 2



CABLE PACK INSERTED INTO GUIDE TUBE
TIME TO 80°C: 35.5 SEC
TIME (SEC)
CABLE PACK INSERTED INTO AND INSULATED FROM GUIDE TUBE
TIME TO 80°C: 36.0 SEC
TIME (SEC)
CABLE PACK WITHOUT TUBE
TIME TO 80°C: 30 SEC
TIME (SEC)

FIGURE 3

4. RGT ROD INSERTION TESTS

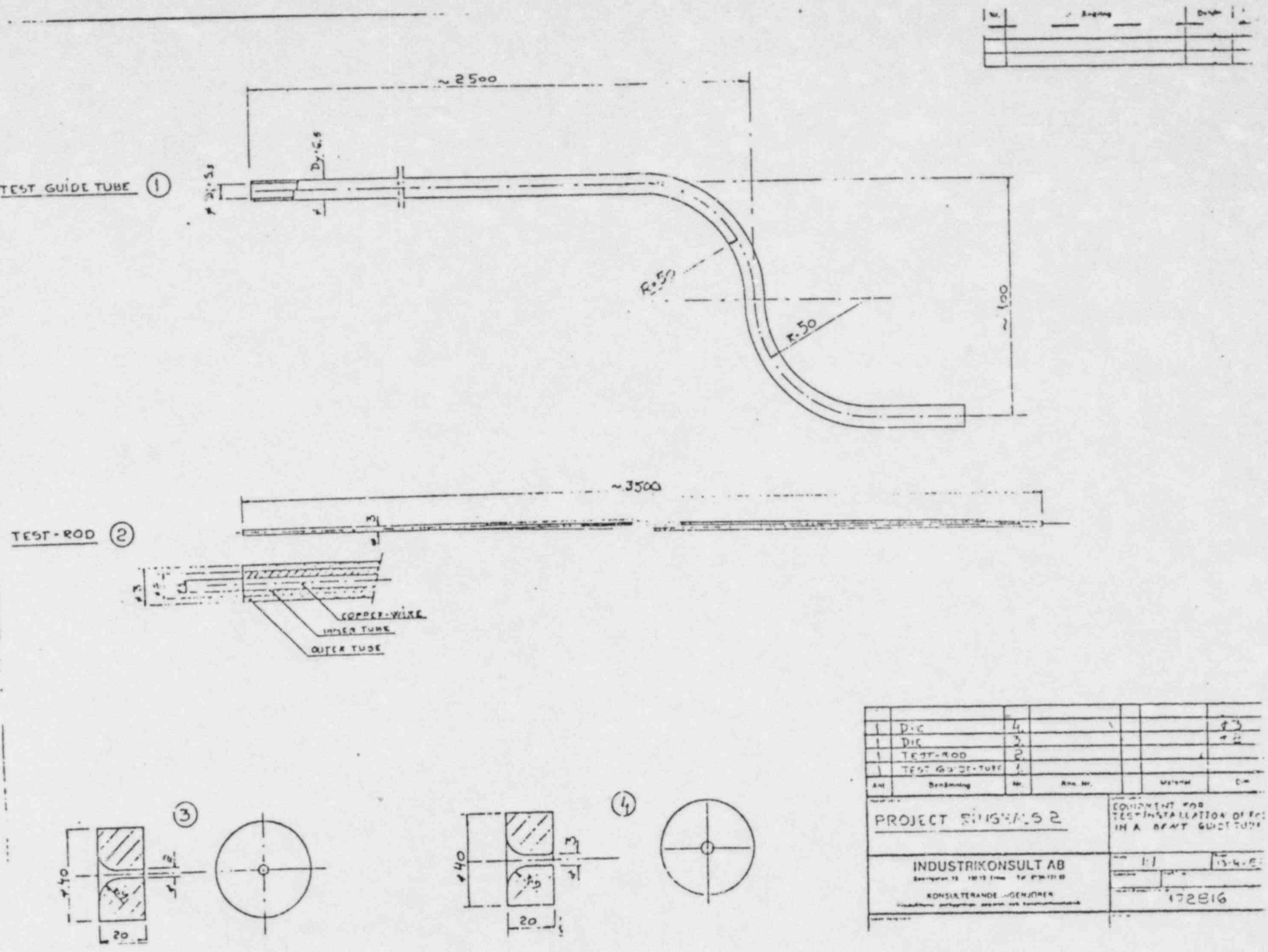
In order to verify that an RGT rod can be inserted into the thermocouple guide tube, a small test was set up.

A mock-up RGT rod was made by drawing two tubes down on a copper wire as shown in the following drawing. The rod had an outer diameter of 3 mm.

The thermocouple guide tube was simulated using a 3.5 meter long tube being bent such that it had the same curvature radius as the guide tube in the reactor (see drawing).

The tests showed that the RGT rod could be inserted passed the two bends without any problem.

In the real guide tube there is another bend at the bottom. The tests carried out can not answer to what extent this bend will create problems during RGT rod insertion.


TEST GUIDE TUBE ①
~2500
R=50
R=50
~100
TEST-ROD ②
~3500
COPPER-WIRE
INNER TUBE
OUTER TUBE
③
20
④
20
40
D:C
D:C
TEST-ROD
TEST GUIDE-TUBE
Benämning
PROJECT
EQUIPMENT FOR TEST INSTALLATION OF FC IN A BENT GUIDE TUBE
INDUSTRIKONSULT AB
KONSULTERANDE INGENJÖRER
1:1
172816