MISSISSIPPI POWER & LIGHT COMPANY
Helping Build Mississippi
P. O. BOX 1640, JACKSON, MISSISSIPPI 39205

NUCLEAR PRODUCTION DEPARTMENT

August 30, 1982

U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D. C. 20555

Attention: Mr. Harold R. Denton, Director

Dear Mr. Denton:

SUBJECT: Grand Gulf Nuclear Station
Units 1 and 2
Docket Nos. 50-416 and 50-417
License No. NPF-13
File 0260/L-860.0
NUREG-0737 (II.F.2):
Instrumentation for Detection of Inadequate Core Cooling
OL Condition 2.C [44(F)], SSER 2, Item 22.2, II.F.2
AECM-82/368

Mississippi Power & Light Company (MP&L) has performed a review of the draft BWR Owners' Group (BWROG) analysis of inadequate core cooling for Boiling Water Reactors (BWR) prepared for the BWROG by S. Levy, Inc. MP&L's review of the draft pre-published report by S. Levy, Inc. titled, "Inadequate Core Cooling Detection in Boiling Water Reactors" (Report No. SLI-8218) is provided as Attachment 1 to this letter.

If you have any questions or require further information, please contact this office.

Yours truly,

John D. Richardson for
L. F. Dale
Manager of Nuclear Services

RAB/SHH/JDR:ac
Attachment: Instrumentation for Detection of Inadequate Core Cooling

cc: See next page

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MISSISSIPPI POWER & LIGHT COMPANY

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ATTACHMENT NO. 1
NUREG-0737, ITEM II.F.2
INSTRUMENTATION FOR DETECTION OF INADEQUATE CORE COOLING

Concern

By August 31, 1982, MP&L shall submit a report addressing the analysis performed by the BWR Owners Group regarding additional instrumentation relative to inadequate core cooling and shall implement the staff's review of this report. These modifications shall be completed on a schedule acceptable to the staff.

Response

INTRODUCTION

The BWR Owners' Group (BWROG) study of inadequate core cooling detection (ICC) in boiling water reactors (BWR) was commissioned by the BWROG (owners) in response to the Nuclear Regulatory Commission's (NRC) plans developed in response to the accident at TMI-2. Those plans included Task II.F.2, "Identification of and recovery from conditions leading to inadequate core cooling." Later via Regulatory Guide 1.97, the NRC indicated that the installation of core thermocouples in BWRs and certain other changes would accomplish Task II.F.2. The General Electric Co. and most, if not all, BWR owners seriously questioned the usefulness and need for core thermcouples in BWRs. GE directly and with the owners reviewed the technical basis for them with the NRC staff without resolution of the issue. Subsequently the owners commissioned a study of incore thermocouples as applied to BWRs. The results of that study confirmed the owner's reservation over incore thermocouples. After presentation of the report and their reservation to the NRC staff, it was mutually agreed a general study of ICC detection in BWRs would be performed. As agreed with the staff, the study was to consider means for providing reliable information to limit core damage during accidents. This was to include the detection of trends toward ICC, the existence of ICC, and the return of adequate core cooling. Also, the cost/benefit of detecting local ICC was to be considered. In addition, the owners wished to determine if additional instrumentation for this purpose was warranted. A report on the detection of ICC to address the above issues is currently in draft form. This summary report is based on the pre-published version of S. Levy's (BWROG Consultant) report titled, "Inadequate Core Cooling Detection in Boiling Water Reactors."

RELATIONSHIP BETWEEN WATER LEVEL AND ICC

To address the above issues the Owners' Group study first examined the relationship between reactor water level and the approach of, existence of and return from ICC. This examination justified reactor vessel water level as a viable indicator of ICC; and the conclusive variable for operational control of BWR reactors for the avoidance or mitigation of ICC.

A more exacting definition of ICC for BWR's was arrived at by the Owners' Group study based on the effects of high temperature on fuel cladding. The peak fuel surface temperature denotative of chemical interaction of the fuel clad material with any available water is the threshold for fuel assembly deterioration affecting the fuel cooling process. The Owners' Group study denotes that peak fuel surface temperatures between 1300°F and 1800°F in an average fuel assembly is a plausibile definition of ICC.

The reactor operational conditions of power level, water level, and recirculation flow were reviewed to identify the operational regimes in which ICC is important or even possible. The constant pressure mode of operation and the controls to assure proper heat removal were outlined. The only significant regime where ICC can be a concern relative to NUREG 0737 Item II.F.2 is a post shutdown decay heat removal regime. This conclusion was drawn after an investigation of various reactor powers, water levels and recirculation flows. At high power ICC is produced by operation beyond the critical heat flux. This condition is precluded by the power-flow trip on the approach to unsafe conditions. At low inventory conditions, ICC is produced by stagnant boiloff as the steam-water mixture height drops below the active length of fuel.

To illustrate the low inventory condition, consider the case of a scrammed reactor with recirculation pumps tripped, vessel isolated, no RCIC or ECCS and no line break, calculations predict fuel channel bypass and downcomer levels are conservative indicators of core water level. The water level measurement system senses level from within the core downcomer zone, which gives the most conservative information on core coverage with respect to water level and hence to peak cladding temperature. It can be concluded from Figure 1 that, for the accident postulated, peak cladding temperature is a function of water level and from Figure 2 that peak cladding temperature has low sensitivity to core uncovery time. Water level is a reliable indicator of peak clad temperature, therefore a reliable indication of the approach to and the existence of ICC. In the event that ICC does take place, the restoration of water level above the top of active fuel will indicate the return to adequate core cooling. Various industry studies and tests (listed below) indicate that core damage will not propagate once the core is recovered.

1. NEDO-20355A, "The Effects of a Large Bundle Flow Area Restriction on the BWR Emergency Core Cooling System Effectiveness", August 1976

2. NEDO-10174, "Consequences of a Postulated Flow Blockage Incident in a BWR", October, 1977.

3. NEDO-10208, "Effects of Fuel Rod Failure on ECCS Performance", August 1970.

ADDITIONAL ICC DETECTION

While water level measurement is the primary ICC detection device in a BWR, there are several others which indicate the adequacy of core cooling. Chief among these is the core spray flow rate. Each of the two core spray systems is capable of cooling the core by spray action. Because they cool by direct spray onto the core, adequate core cooling is provided independent of water level. Thus, if the measured flow of either spray system reaches or exceeds rated flow, adequate core cooling is indicated.

Flows to and from the vessel are indications which confirm or support water level indication. Level indication trends must be consistent with the vessel inventory changes inferred by these flows. As an example, consider a case of interest from an inadequate core cooling standpoint. Assume the reactor has entered an isolation status and that a high-pressure injection system is making up inventory. Assume, also, as would be expected, that the indicated level moves from normal level to high level. The automatic control systems or operator can be expected to turn off all injection as a result. Now, postulate that this upward indication movement was the result of level indication failures which were undetected by the level measurement validation process. These failures will be revealed by the operator observing that level indications do not fall even though there is no flow to the vessel and the safety/relief valves periodically opening and removing inventory. As has been shown, it would take over 40 minutes for the actual level to reach the top of the core. Therefore, there is considerable time available to observe the inconsistency between the indicated level trend and the lack of inventory makeup.

Should ICC conditions exist, they would be revealed by containment gross gamma, containment hydrogen concentration, and reactor and suppression pool water sample activity measurements.

RISK CONTRIBUTION OF CURRENT ICC SYSTEM

The risk contribution of the water level measurement system to core degradation probability was evaluated based on modifying an existing PRA for a BWR-4 plant with a Mark-II containment. The core power density and plant pressure rates on a BWR-4 are between those of earlier and later plant designs. The Mark II containment in the reference plant represents an evolutionary step between the Mark I and Mark III containments.

The uncertainty in the calculated best estimate frequency of core melt in the subject PRA had been quoted as approximately a factor of 20. From this is can be seen that the absolute value of core melt frequency may be significantly higher than the best estimate value quoted here. Specifically, the core melt frequency could be in the range of 10^{-4}/year and still be within the 90% confidence interval.

The selected BWR is therefore broadly representative of the total BWR population. However, this is not meant to imply that the results given here may be applied to a specific plant. There are considerable differences between plants that would affect the calculated core melt frequencies, and plant-specific analysis would be required to identify core melt frequencies for a particular plant. The results provided are indicative of the relative contribution of the water level system for a "typical" plant.

In the subject PRA, three sources of water level indication error were not considered in the original PRA. They are: 1) loss of drywell cooling; 2) instrument line failure; 3) level instrument failure. Event trees of the subject PRA were modified to include contribution of the above sources of water-level indicator errors. Comparison of original degraded core frequency to the degraded core frequency calculated in this study revealed the following contributions stated in event frequency and as percentage of the original total event frequency (14 events/million years):

Loss of drywell cooling	0.74 events/million years	[illegible]3%
Instrument line break	0.58 events/million years	4.[illegible]%
Instrument failures	0.46 events/million years	3.2%
TOTAL	1.78 events/million years	12.6%

COST EFFECTIVE BACKUP TO WATER LEVEL MEASUREMENT

To evaluate cost effective backups to water level, alternative core cooling measurement devices were evaluated. A broad spectrum of possible devices (Table 1) were subjected to preliminary screening, performance evaluation, and finally a cost comparison to determine four viable possibilities.

Heated Junction Thermocouples in LPRM tubes can detect the presence of water (level) by measuring the heat transfer rate capability at the sensor location via a change in temperature difference between the heated and the non-heated thermocouples. Normal thermocouples in LPRM tubes could detect ICC in some cases but would suffer from ambiguous outputs. Thermocouples located in the steam dome are at best as good an indicator as the above T/C's in LPRM tubes. Normal thermocouples placed in the LPRM tubes or steam dome would have appreciable time lag that would prevent detection of the approach to inadequate core cooling. SRM detectors may be able to sense ICC by a sudden drop in thermal neutron flux when water level drops below the SRM detectors, but considerable development work is needed for these devices. Costs of these four alternatives are summarized in Table 2.

A cost/benefit exercise based on an NRC proposed technique (SECY 81-513 August 1981) for prioritizing safety issues was used. EPRI RP-1585 published June 1982 catagorizes the priority score as follows:

$S = 1 - 1{,}000$ Low
$1{,}000 - 10{,}000$ Medium
greater than 10,000 High

$$S = \frac{\text{Safety Benefit}}{\text{Cost}} = \frac{N \triangle [FR]\, R^{0.2}}{C + NI}$$

where,

S = Priority score

N = Number of reactors affected

R = Consequences, in curies released

$R^{0.2}$ = Weighting Factor

F = Event frequency in events per reactors years

C = Forward looking NRC cost in millions of dollars

I = Forward looking industry cost in millions of dollars per reactor

$\triangle$ = Mathematical operator to indicate the change in the quantity within the brackets.

The NRC priority score falls well within the low priority range (S=91) based on an alternative device increasing the probability of recognizing the threat of ICC by a factor of 5 (training on procedures) and a cost of $3 million for a new device. The factor of five means additional instrumentation would inform the operator of ICC so that he could take manual action not previously taken, and that the operator would successfully perform the desired function. A range was calculated of S=8 to 1030 based on the square root of the sum of the squares of the assumed uncertainty in each term. This analysis supports our position that such a fix is also very low priority for Grand Gulf.

CONCLUSION

In conclusion, the draft BWR Owners' Group analysis of Inadequate Core Cooling demonstrates that knowledge of measured reactor vessel water level provides a reliable means of determing whether the core is adequately cooled. Grand Gulf's full range of vessel water level measurement, procedures, and training gives the operator indication and instructions for proper actions. Reliabile information to limit core damage is provided at Grand Gulf. Detection and trending of the approach to ICC is measured by the existing Grand Gulf water level system in that the relationship of water level and approach to ICC was established in the Draft Owners' Group Report. It was determined that it is not cost beneficial to detect local ICC. Although many devices for ICC detection were evaluated generically, they are not expected to survive extreme conditions long enough to provide significant information for local ICC detection. In light of the low degree of risk and existing ICC detection, it is determined that no additional instrumentation is needed to detect inadequate core cooling. As shown in Figure 3, the risk remaining after either additional ICC devices or improved water level measurement reliability improvements is diminishingly small, indicating that the application of both additional ICC devices and water level measurement reliability improvements is not warranted.

TABLE 1

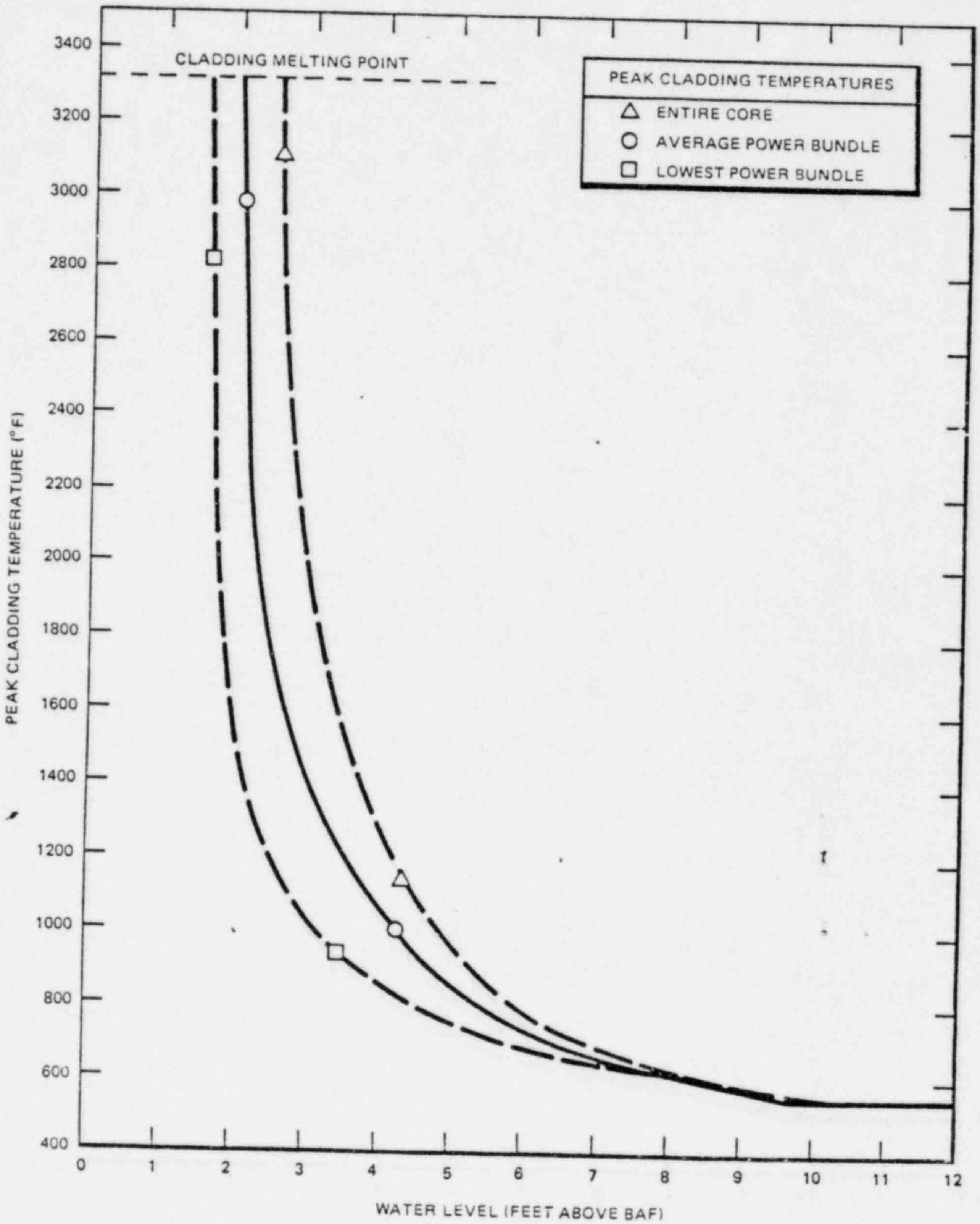
POSSIBLE ICC DETECTION DEVICES

NAME OF DEVICE	NAME OF DEVICE
Source Range Monitor	Wave Guide
Intermediate Range Monitor	Vessel Weight
Local Power Range Monitor	Vessel Vibrations
Traveling Incore Probe	Floats
Gamma-Neutron Reaction Detector	Conductivity Probe
Gamma Attenuation	Capacitance Probe
Gamma Void Meter	Sonic Reflection
Neutron Modulation Void Meter	Loose Parts Monitor
Core Reactivity Detector	Microwave Probe
Fuel Plenum Tracer	Mass Balance
Primary System Activity Meter	Differential Expansion Integral Anemometer
Incore Thermocouples	Delta-P Bubbler
Heated Junction Thermocouples	Self-Powered Neutron Detector
Gamma Thermometers	Resistance Temperature Detectors
Control Rod Drive Thermocouples	Steam Dome Thermocouples
Sight Glass	Liquid Level and Void Fraction Detector
Cerenkov Light Detector	

TABLE 2

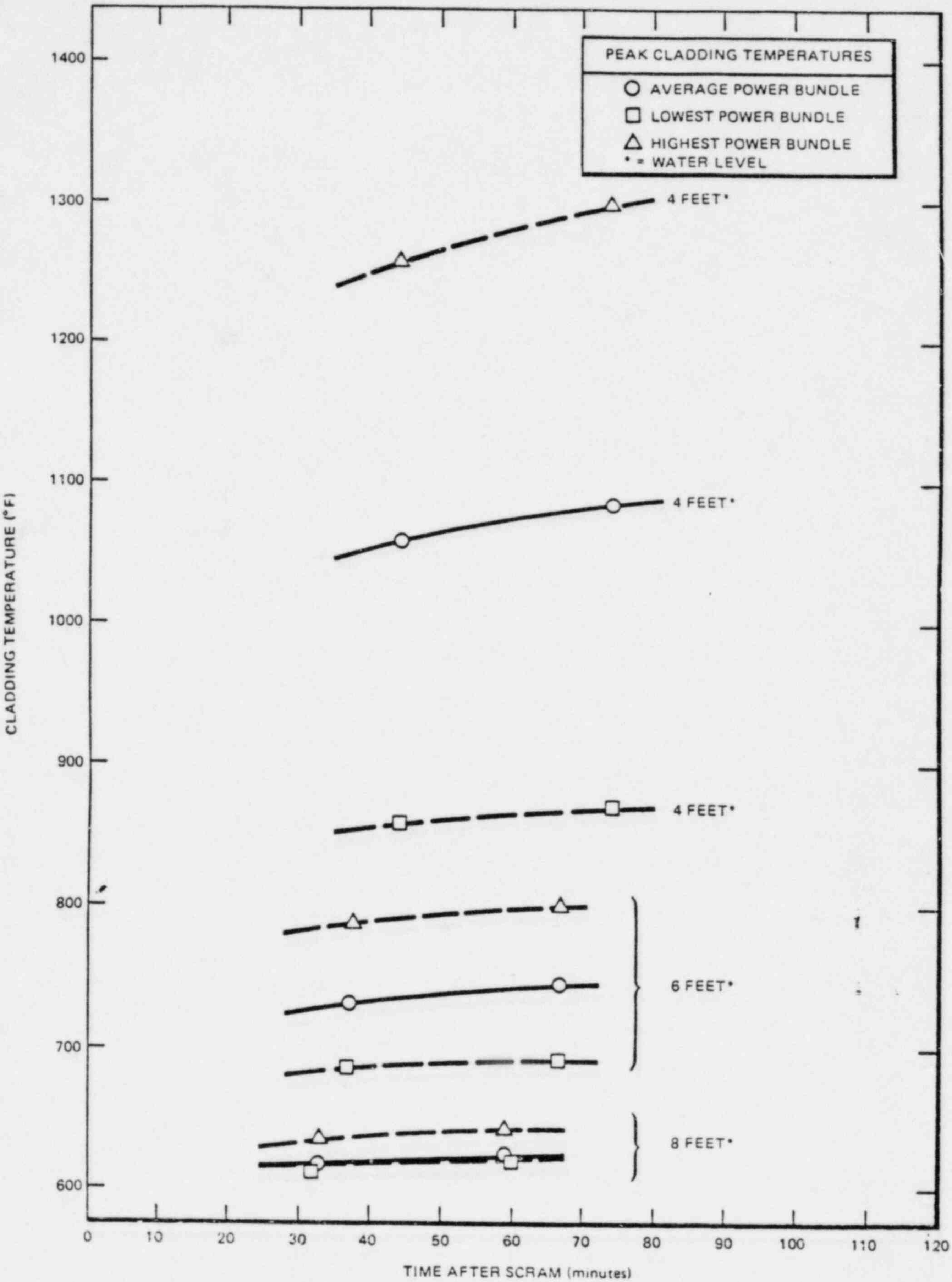
COST SUMMARY OF ALTERNATIVE ICC DETECTION DEVICES

	COST	EXPOSURE MAN/REM MIN.	EXPOSURE MAN/REM MAX.
HJTC	$2.9 Million	65	450
T/C (LPRM)	$2.5 Million	65	450
T/C (st. dome)	$ .8 Million	16	80
SRM	$1.3 Million	16	100



Water Level As An Indicator of Core Overheating

Figure 1



Cladding Temperature Sensitivity to Core Uncovery Time

Figure 2

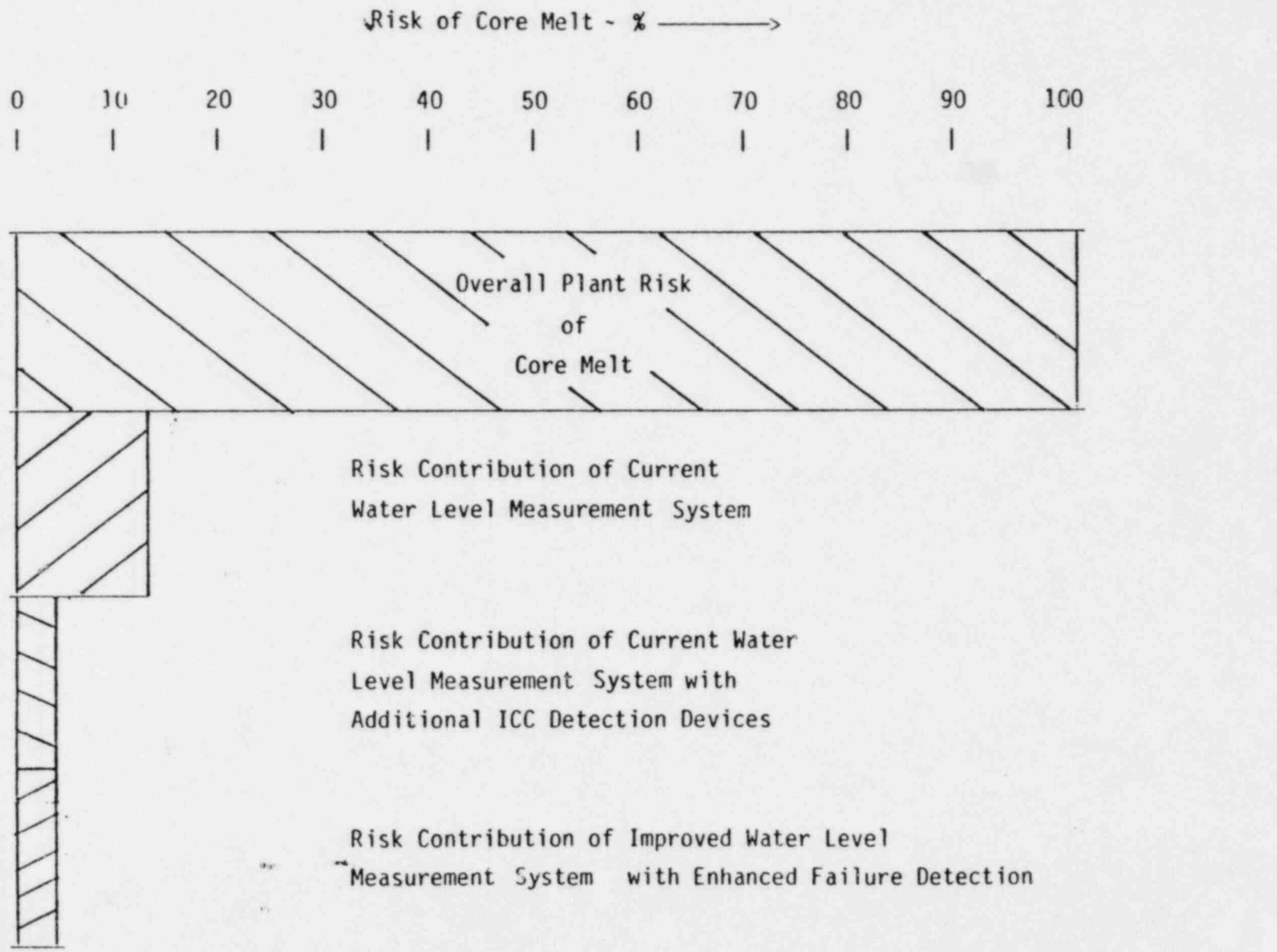

Risk of Core Melt ~ % ———>
0
10
20
30
40
50
60
70
80
90
100
Overall Plant Risk
of
Core Melt
Risk Contribution of Current
Water Level Measurement System
Risk Contribution of Current Water
Level Measurement System with
Additional ICC Detection Devices
Risk Contribution of Improved Water Level
Measurement System with Enhanced Failure Detection
Relative Risk Contribution

Figure 3