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July 28, 1982

Mr. A. Schwencer, Chief
Licensing Branch #2
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: LaSalle County Station Units 1 and 2
Instrumentation for Detection of
Inadequate Core Cooling
NRC Docket Nos. 50-373 and 50-374

Reference (a): License NPF-11 dated April 17, 1982
Condition 2.C.(30).(i), Instrumentation
for Detection of Inadequate Core
Cooling.

Dear Mr. Schwencer:

Reference (a) states, in part, that:

> "By July 31, 1982, the licensee shall submit a report addressing the analysis performed by the BWR Owners Group regarding additional instrumentation relative to inadequate core cooling....."

Attached please find Commonwealth Edison Company's report which fulfills this dated requirement.

To the best of my knowledge and belief the statements contained herein and in the attachment are true and correct. In some respects, these statements are not based on my personal knowledge but upon information furnished by other Commonwealth Edison and contractor personnel. Such information has been reviewed in accordance with Company practice and I believe it to be reliable.

If you have any further questions in this matter, please contact this office.

Very truly yours,

CW Schroeder 7/30/82

C. W. Schroeder
Nuclear Licensing Administrator

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cc: NRC Resident Inspector - LSCS

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NUREG 0737 Item II.F.2 Inadequate Core Cooling

Background

The BWR Owners' Group met with the NRC Staff on January 26, 1982 to discuss the continuation of activities under NUREG 0737, II.F.2, Inadequate Core Cooling (ICC). It was agreed to more specifically respond to NRC concerns on 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 to adequate core cooling. The cost/benefit of detecting local ICC was to be considered. Additionally, a cost effective backup to water level measurement would be explored. A study of the detection of ICC to address the above issues was commissioned by the BWR Owners' Group and is currently in draft form. These preliminary comments are of necessity related to the pre-published version of S. Levy's "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 to, 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 specific definition of ICC for BWR's was made based on the effects of high temperature on fuel cladding. The peak fuel surface temperature indicative of chemical interaction of the clad material is the significant threshold for fuel bundle deterioration affecting cooling processes. A peak fuel surface temperature near 1800°F defines 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 normal 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 conditions consider the case of a scrammed reactor with recirc 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. Figure 2 can be generalized to many other events. (The effect of constant vessel pressure is also a conservatism). 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 [1,2,3] listed below indicate that core damage will not propagate once the core is recovered. Vessel water level is also a good indication of return to adequate core cooling.

Additional ICC Detection Capabilities in the BWR

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 the minimum required flow, there is no way for peak clad temperature to rise.

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 the high-pressure injection system is making up inventory. Assume also, as would be expected, that the level measurements move from normal level to high level. The automatic control systems or operator can be expected to turn off all water injection as a result. Now, postulate that this upward indication movement was the result of a failure which was undetected by the level validation process. Subsequently, actual level must decrease as inventory is lost through the safety/relief valves when

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[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.

there is no makeup to the vessel. If indicated level does not decrease, the level failure is revealed. Further, the discrepancy becomes larger with time. It can be shown, it would take over 40 minutes for the actual level to reach the top of the core. For the indicated levels to remain high for this interval of time without flow to the vessel is a clear indication of level indicator failure.

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

Location of ICC Detection

No instrumentation located in the vicinity of local fuel failures would survive the environment caused by the degree of damage required to inhibit core cooling. Many devices for ICC detection were evaluated in the Owners' Group Report and are listed later in this document. Because damage propagation subsequent to recovery would be restricted and because local detectors would be destroyed before significant information could be obtained from them, local detection of ICC is not feasible. Failure of such instruments is not a conclusive indicator of ICC.

The ASSESSMENT OF FAILURES IN EXISTING WATER LEVEL EQUIPMENT Owners' Group Report made an assessment of the risk associated with the existing water level measurement system. Probabilistic Risk Assessment (PRA) techniques quantified the "marginal risk" presented by failures in the measurement of vessel water level as they impact automatic initiation of safety systems and as they potentially effect plant operator responses. This was done to put into perspective any potential risk reduction that is postulated by employing additional ICC devices in the BWR.

The risk contribution of the water level measurement system to core degradation probability was first evaluated based on modifying an existing PRA for a BWR-4 plant with a Mark-II containment. Design similarities between the subject of that PRA and LaSalle exist such that the general conclusion from this study can be applied to LaSalle. The two sources of water level indication error were not considered in the original PRA. They are: loss of valid water level signal with elevated drywell temperatures and low vessel pressure; and susceptibility of some systems to common instrument line breaks in selected locations plus concurrent failure of certain level instruments. Event trees of the original 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	0.28 events/million years	2.0%
Instrument line break	0.11 events/million years	0.8%
Instrument failures	0.35 events/million years	2.5%
Total	0.74 events/million years	5.3%

COST EFFECTIVE BACKUP TO WATER LEVEL MEASUREMENT

Next, 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 for 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 type nuclear detectors may be able sense loss of moderator by a sudden drop in detected thermal neutron flux, 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 - 1000 Low
1,000 - 10,000 Medium
greater than 10,000 High

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

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

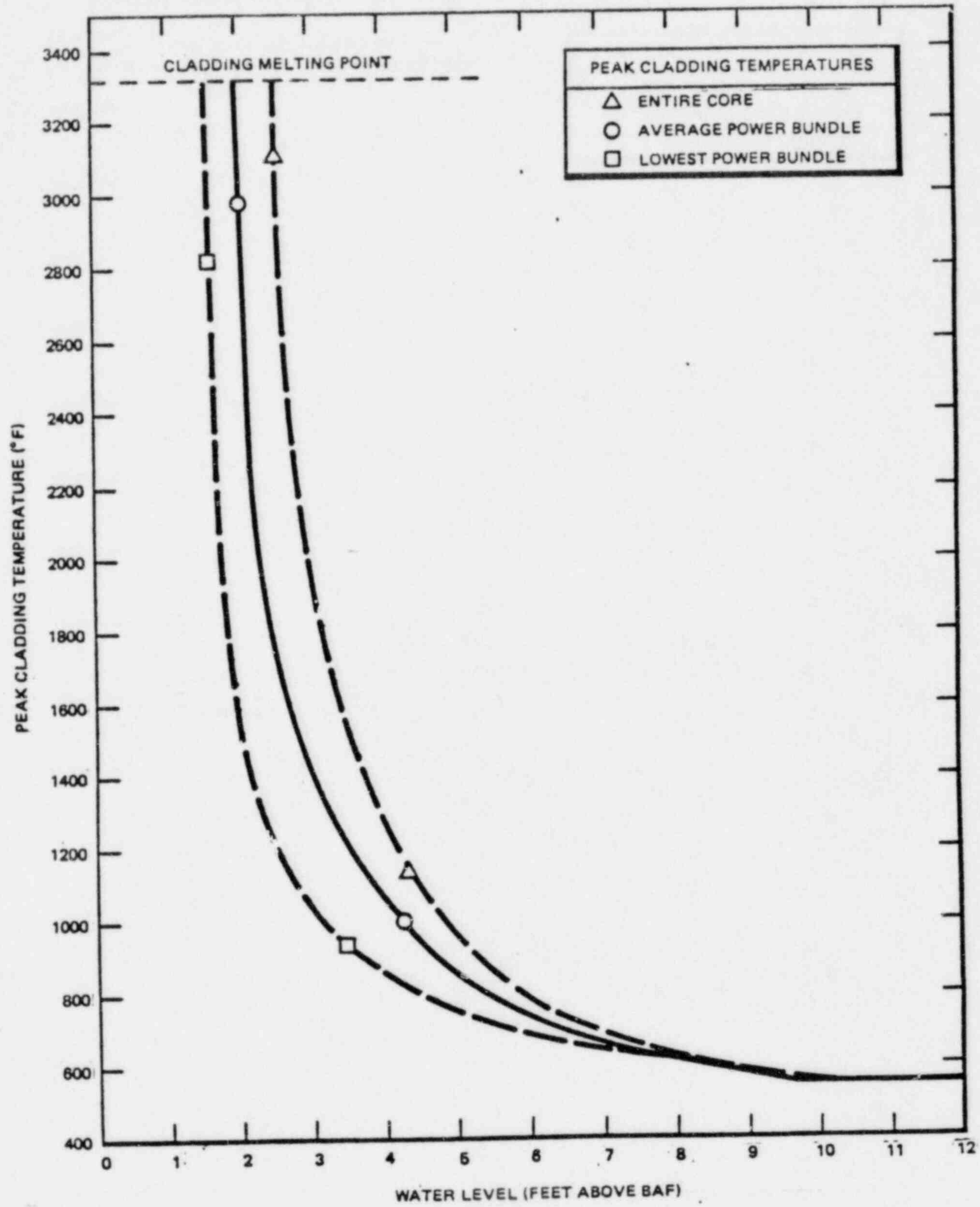
I = Forward looking industry cost in millions of dollars per reactor

Δ = Mathematical operator to indicate the change in the quantity within the brackets

The NRC priority score falls well within the low priority range (S=35) 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. A range was calculated of S=3 to 400 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 LaSalle. 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.

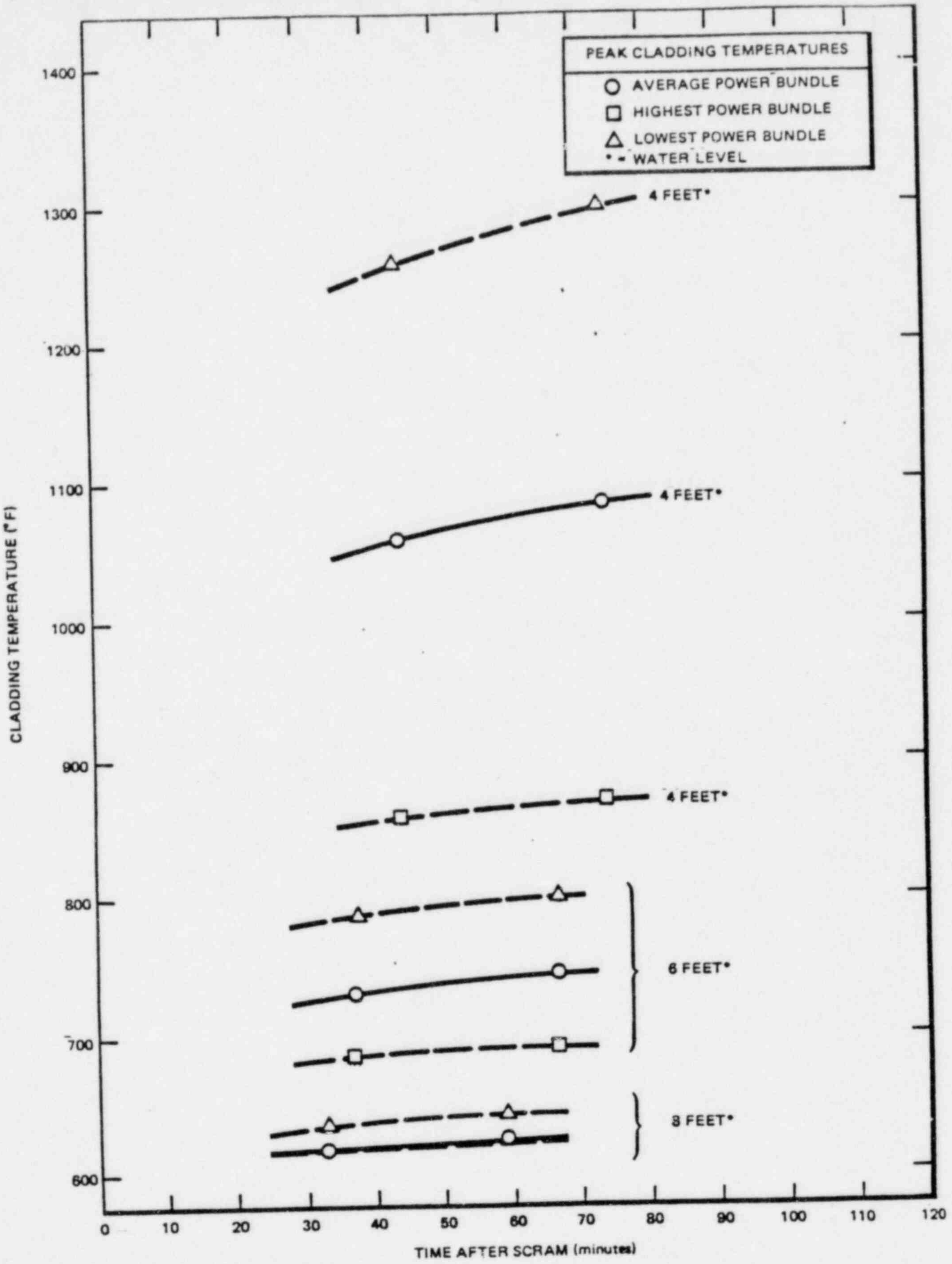
Conclusion

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. LaSalle'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 LaSalle. Detection and trending of the approach to ICC is measured by the existing LaSalle 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. No additional instrumentation is warranted.



Water Level As An Indicator of Core Overheating

Figure 3-6



Cladding Temperature Sensitivity to Core Uncovery Time

Figure 3-7

Table 1

Possible ICC Detection Devices

Name of Device

- Source Range Monitor
- Intermediate Range Monitor
- Local Power Range Monitor
- Traveling Incore Probe
- Gamma-Neutron Reaction Detector
- Gamma Attenuation
- Gamma Void Meter
- Neutron Modulation Void Meter
- Core Reactivity Detector
- Fuel Plenum Tracer
- Primary System Activity Meter
- Incore Thermocouples
- Heated Junction Thermocouples
- Gamma Thermometers
- Control Rod Drive Thermocouples
- Sight Glass
- Cerenkov Light Detector

Name of Device

- Wave Guide
- Vessel Weight
- Vessel Vibrations
- Floats
- Conductivity Probe
- Capacitance Probe
- Sonic Reflection
- Loose Parts Monitor
- Microwave Probe
- Mass Balance
- Differential Expansion Integal Anemometer
- Delta-P Bubbler
- Self-Powered Neutron Detector
- Resistance Temperature Detectors
- Steam Dome Thermocouples
- Liquid Level and Void Fraction Detector

Table 2

COST SUMMARY OF ALTERNATIVE ICC DETECTION DEVICES

		Exposure Man/Rem	
	Cost	Min.	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