STATUS SUMMARY

TMI ACTION PLAN II.F.2

"COST/BENEFIT STUDY OF DESIGN REQUIREMENTS FOR INADEQUATE CORE COOLING INSTRUMENTATION"

JUNE 1982

PREPARED FOR:
BRIEFING OF CRGR

PREPARED BY:

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1.0 INTRODUCTION

A briefing on TMI Action Plan Item II.F.2 requirements was given by the NRC staff to the CRGR on March 24, 1982. As a result of the briefing, additional information addressing some open technical issues and a cost/benefit study for ICC instrumentation was identified as outstanding. The purpose of the cost/benefit study was to compare the possible benefit to be obtained against the cost to meet major design requirements specified in Item II.F.2 of NUREG-0737.

Regarding the open technical issues, a letter requesting additional information, including a failure mode and effects analysis (FMEA), was sent to Westinghouse and Combustion Engineering in April 1982 (A1 and A2 in Appendix A). We have reviewed their responses to our specific request for additional information relative to their failure mode and effects analyses (FMEA) and found both CE and Westinghouse Owner's Group responses (A5 and A6 in Appendix A) satisfactory. We have also reviewed the CE Owner's Group responses to questions concerning the performance of their heated junction thermocouple (HJTC) level measurement system with a small break located within and external to the upper head and after a large break LOCA (A6 in Appendix A) and have found their responses acceptable (A7 and A8 in Appendix A). We plan to issue a supplemental Technical Evaluation Report on these systems which will find the generic design to be acceptable.

A letter requesting additional cost data for a cost/benefit study was sent from R. Mattson (NRC) to Westinghouse, the Westinghouse Owners' Group, Combustion Engineering, the CE Owners' Group, B&W, the B&W Owners' Group, and the AIF (A3 in Appendix A). The design options identified for consideration in preparation of the cost/benefit study were:

Option 1: Reference design - meets all NUREG-0737 design requirements.
Option 2: Delete all seismic design requirements from reference design.
Option 3: Delete environmental qualification requirements, except seismic, from reference design. In this option, when we say

"delete environmental qualification", we mean that there need be no qualification by testing under expected accident conditions, but that the equipment would be expected, by design or analysis, to survive and function under design basis accident conditions.

Option 4: Delete single failure design requirements (redundancy) from reference design.

Option 5: Delete Class 1E power source requirement from reference design.

Option 6: Respondents' Recommended Design (Describe differences relative to Option 1).

The industry has responded to our request for the cost/benefit data and the staff has analyzed the data. This report presents the results of the staff's review and provides our recommendations and bases for retention or revision of NUREG-0737 design requirements for inadequate core cooling (II.F.2) instrumentation. A copy of all correspondence responding to our request is available in Appendix B to this report, which includes vendor-proprietary information.

2.0 SUMMARY OF INDUSTRY DESIGN RECOMMENDATIONS

Industry cost estimators were invited to provide estimates and comments concerning Option 6, which would be their recommended optimum design based on cost/benefit considerations. Although no one responded completely to Option 6, some design recommendations relating to specific instrumentation systems which were provided in their responses relevant to the optimization of design requirements are included in Sections 2.1 to 2.4 of this report. In general, the respondents concluded:

(1) Due to the advanced status already achieved by licensees in the design, fabrication, and qualification of the ICC instrumentation for many plants and due to the necessary integration of this instrumentation with the reactor coolant system and associated critical safety functions being monitored by the operator, cost reductions for equipment procurement could not be achieved by relaxing the NUREG-0737 design requirements at this time.

(2) Redundant instrumentation channels are recommended for availability considerations even if single failure design requirements are eliminated.

2.1 Core Exit Thermocouples

(a) Use the existing core exit thermocouples (CET) and upgrade the cables, reference junction, and electrical penetrations to meet NUREG-0737 requirements.

Estimated Cost - $500,000 for the cited work. This does not address the display system.

(b) Use the existing plant computer, CRT displays, alarms and recording equipment (all non-class IE and non-seismic Category 1) and existing incore thermocouples. Replace existing incore thermocouple connectors used for disconnecting the thermocouples when the reactor head is removed.

Estimated Cost - $250,000 for design and installation of hardware and for licensing, qualification testing, calibration, and maintenance for forward fit. $170,000 to qualify existing cables and connectors for backfit.

NOTE: This estimate is apparently based on the upgrading of a design which meets qualification requirements but must be qualified by testing. The estimates imply that installed cabling and connectors on some Westinghouse plants are capable of meeting environmental qualification requirements.

2.2 Subcooling Margin Monitor

(a) B&W Owners recommend use of existing subcooling margin monitors.

(b) Westinghouse Owners recommend use of existing plant computer outputs for temperature and pressure, and installation of a vendor supplied display for subcooling margin.

(c) AIF recommends use of the existing plant computer, CRT displays, alarms, recording equipment (all non-class IE and non-seismic Category I) and existing resistance temperature devices (RTD's). They suggest replacing the wide range pressure indicators with three new class 1E dual scale indicators for each unit that would register both reactor coolant system pressure and the corresponding saturation temperature (Tsat) from three channels (safety grade) of input signals. The dual indicators enable the operator to directly read Tsat and compare it to the average RCS temperature to determine the subcooling margin. This would require no added maintenance above that currently performed.

Estimated Cost - $5,000 for design, hardware, installation and calibration.

2.3 Inventory Trending with RCS Pumps Off

(a) B&W Owners recommend use of two redundant d/p transmitters monitoring the upper 19 feet of hot leg piping for detection of an approach to ICC. The system would require no new reactor coolant system penetrations, minimizes exposure to personnel, would require a shorter installation (down) time, and have a significant cost savings compared to Option 1.

(b) Westinghouse Owners recommend use of a utility designed d/p system, similar to the one at Point Beach, which complies with NUREG-0737 requirements or a combined system of neutron detection vessel level instruments in combination with thermocouples in the vessel head for indication of a bubble near the top of the vessel or pulsed and heated thermocouples to determine vessel level.

(c) CE Owners are concerned with the cost level for Option 1 but could not identify any recommended alternatives.

2.4 Inventory Trending with RCS Pumps On

Where needed to supplement the pumps off inventory trending system, reactor coolant pump current monitors have been recommended at a cost of $200,000 to $280,000.

3.0 CONSIDERATION OF INDUSTRY COST DATA

3.1 Discussion of Data

The cost estimates for upgrading all of the inadequate core cooling intrumentation to meet NUREG-0737 requirements (Option 1) shows wide variation and makes interpretation difficult. The range of cost estimates follows:

Instrumentation Type	Cost Range*
Core Exit Thermocouples	$648,000 to $6,280,000 back fit $551,000 to $1,250,000 forward fit
Subcooling Margin Monitors	$70,000 to $500,000 back fit $100,000 to $1,750,000 forward fit
Inventory Trending with RCS Pumps Off	$1,530,000 to $5,280,000 back fit $195,000 to $3,694,000 forward fit
Inventory Trending with RCS Pumps On (Reactor Coolant Pump Current Monitor)	$200,000 to $280,000

The cost sampling is small, not completely defined, and not necessarily representative. There are several apparent reasons for the diverse estimates for Option 1 which necessarily impact the assessment of the other options. These are described in the next four paragraphs.

(a) Generic Design Variations

Westinghouse and Combustion Engineering have inventory trend monitor systems which differ in design principle. Both have been reviewed and meet NUREG-0737 design requirements. Although cost data provided by the vendors indicate that the procurement costs for these systems are comparable, installation costs vary considerably. The staff review of the B&W proposed inventory trending

*Corresponding backfit and forward fit cost data were not provided by all estimate sources; however, backfit cost estimates exceeded corresponding forward fit cost estimates in all cases.

system has not been completed and design changes which impact the cost may be required to make the system acceptable. The system design variations among suppliers are also important when considering the impact of the design options on cost. The Westinghouse system is designed with the d/p transmitters and channel electronics external to containment. Since the design requirements are much more stringent for equipment within containment, the potential cost reductions for the Westinghouse system from relaxation of seismic and environmental design requirements are small compared to the B&W and CE designs. The cost estimates tend to confirm this observation. In addition, with the Westinghouse and CE generic designs inventory trending with the RCS pumps running can be accomplished with the "pumps off" system. However, the B&W generic design must provide either RCS pump power or pump current monitors to accomplish this function at a cost estimated at between $200,000 and $280,000.

The costs to upgrade the existing core exit thermocouples and subcooling margin monitors are likewise dependent on the original design specifications. Although the reason is not apparent, the data provided by the industry does indicate that the seismic and environmental requirements have substantially less impact on upgrading costs for Westinghouse and B&W plants than for CE plants. This may be because the CE data are based on upgrading costs for San Onofre 2 and 3 only, which show substantially higher overall costs than for upgrading the CETs in B&W and W plants. Part of the high cost is because $2,000,000 of the $3,000,000 cost for an integrated process and display system (included as a design option) have been allocated to the CET system (the other $1,000,000 is allocated to the inventory trend monitor). It is also important to note that the projected savings from deleting the environmental qualification requirement (Option 3) is not valid in the San Onofre estimate. The cost estimates for Option 3 were intended to consider the deletion of the qualification testing requirement, but were still expected to assume that the designs would survive and function under accident conditions. The cost estimate submitted for CE plants went beyond this and assumes that the design need not withstand the accident environment and uses cheaper material (e.g. organic cable instead of mineral-insulated cable).

(b) Plant Specific Design Variations

The plant specific cost for upgrading core exit thermocouple systems and subcooling margin monitors are highly dependent on the original installation. Older plants tend to require more design changes in order to upgrade existing systems to an acceptable level, whereas some of the newer plants need only qualify the existing installations.

(c) Backfit Versus Forward Fit

Older reactors are likely to have unique upgrading problems which can escalate the installation costs. For example, Beaver Valley Unit 1 requires extensive cable and conduit routing inside containment for the inventory trending monitor. The cable and conduit includes temperature compensation for the d/p transmitters, and results in an upgrading cost of $3,694,000. A similar system installed in a more recently licensed plant where the need for TMI upgrade was recognized early in the licensing review, resulted in an actual expenditure of $878,000.

(d) Cost Estimate Uncertainty

There is considerable uncertainty in the cost estimates and in the bases for the cost estimates, e.g., how are the costs for the integrated process and display system allocated to the inadequate core cooling instrumentation. In Table 2 of the report prepared for our March 24 briefing of CRGR (transmitted by letter, H. Denton to V. Stello, dated March 16, 1982), the CE RVLMS (trend monitoring) system was estimated for San Onofre at a cost of $1,600,000 including installation costs. In the new estimate which was prepared to show potential savings by reduction of design requirements, the installation costs have increased by $2,700,000. In addition, a cost of $3,000,000 is indicated for the integrated process and display system for a single plant. We have assumed that this is the ICC instrument portion instead of total cost, and have allocated about 2/3 to the CET system and 1/3 to the inventory trending system. When queried, Southern California Edison personnel indicated that the new cost estimates are more accurate. The change in the estimate for this plant from $1,600,00 to 5,280,000 has helped to raise the average cost from under $2,000,000 in the old estimate to $3,176,000 in the new estimate.

3.2 Presentation of Data

Based on all of the cost/benefit data provided by the industry, the staff has used a cost weighting factor to determine a representative cost for making its comparisons to potential benefits associated with each of the major design requirements in Item II.F.2 of NUREG-0737. The costs for each plant type and the cost reduction attributable to each design option (2 through 5) are presented for core exit thermocouples, subcooling margin monitors, inventory trending with RCS pumps off and inventory trending with RCS pumps on in Tables 1 through 4, respectively. Proprietary versions of these tables are provided in Appendix B. Table 5 provides a summary of the cost data and percent saving associated with each of the design options (2 through 5) for all of the ICC instrumentation.

4.0 COST/BENEFIT CONSIDERATIONS FOR DESIGN OPTIONS

4.1 Core Exit Thermocouples

4.1.1 Delete Seismic Design Requirements (Option 2)

This option, as shown in Table I, would result in an average cost reduction of 14% for the estimated plants. This would result in a savings of $300,000 on the average cost ($2,148,000) for a backfit system and $142,000 for a forward fit plant.

The ICC instrumentation is intended to function to monitor core cooling for both design basis and beyond-design basis accidents. Failure to design the instrumentation to withstand seismic events may significantly reduce the probability of having an operable ICC instrumentation system for a severe accident caused by a large earthquake. Several recent state-of-the-art PRAs have shown seismic risk to be dominant. While the potential savings by deleting seismic design requirements for the CET system is not trivial, it is probably too small in most cases to justify potential unavailability of this instrumentation for large seismic events.

4.1.2 Delete Environmental Qualification Requirements (Option 3)

Implementation of Option 3 (see Table 1) would result in either an average cost reduction of 35 percent ($752,000 for an average cost CET system) or, if the data from the B&W Owners Group and San Onofre were discounted, in a more realistic 17 percent reduction ($293,000 savings). The intent of this option was to delete environmental qualification testing requirements while continuing to provide a system which was expected to survive and function under design basis accident conditions.

Unfortunately, industry responses relative to Option 3 were unable to make the distinction between a CET design which was environmentally fully-qualified and one which was designed to environmental standards but not qualified by environmental testing. The staff would find it difficult to evaluate the design intent and environmental capability of a CET system designed under Option 3. Since the adoption of Option 3 as a design requirement for the CET system would likely result in some confusion and uncertainty, we believe that it is not workable.

We further conclude that it is essential that the required instrumentation be capable of surviving the accident environment to which it is exposed for the length of time its function is required. The savings by deleting environmental qualification requirements for the CET system cannot be justified by the possible greater benefit to be obtained from the availability of instrumentation which is qualified to more stringent environmental requirements and which would provide needed information for an operator in order that unplanned action can be taken when necessary.

4.1.3 Delete Single Failure Design Requirements (Option 4)

This option (see Table 1) would result in an average cost reduction of 21% for the estimated plants. The savings on an average cost CET system would be $450,000 for backfit and $210,000 for forward fit. The cost impact for the single failure design is reasonably consistent for most of the estimated plants.

Some industry comments have indicated that redundant instrument channels should be retained for availability considerations. If we require that one channel of ICC instrumentation be operable during plant operation (presently proposed technical specifications), it appears that the potential costs in plant downtime would easily justify the necessary expenditures for single failure design capability.

4.1.4 Delete Class 1E Power Source (Option 5)

The cost estimates have indicated little or no savings (see Table 1) associated with Option 5. The average cost reduction of 3 percent for a backfit plant would amount to \$65,000 for an average cost CET system.

The small savings associated with Option 5 appear to be insufficient to justify the increased vulnerability of the CET system to a loss of functional capability.

4.2 Subcooling Margin Monitor

Table 2 indicates that the average cost of a subcooling margin monitor for the estimated plants is \$325,000 for backfit and \$658,000 for forward fit. It was expected that forward fit would actually cost less than back fit. The contrary indication in Table 2 is believed to be due to the particular sampling of estimates and estimate error.

The average savings associated with design options 2 thru 5 respectively are 19%, 30%, 30% and 2% for backfit, and 16%, 15%, 30%, and 10% for forward fit.

The subcooling margin monitors are relatively low in cost and are a significant indicator for operator actions in emergency operating procedures. It is, doubtful that the small savings (\$100,000) which could be achieved by any of the alternate design options would justify the potential loss of reliability and/or availability associated with the reduced design requirements.

4.3 Inventory Trending with RCS Pumps Off

4.3.1 Delete Seismic Design Requirements (Option 2)

The data in Table 3 show that this option would result in an average cost reduction of 9% for the estimated plants. The savings would be $285,000 based on the average cost ($3,176,000) for estimated backfit systems and $73,000 for a forward fit plant.

The potential savings are about the same as Option 2 savings for the core exit thermocouple system and the Section 4.1.1 discussion of seismic design benefits for ICC instrumentation is applicable to the inventory trending monitor.

4.3.2 Delete Environmental Qualification Requirements (Option 3)

This option (Table 3) would result in an average cost reduction of 16% for the estimated plants. The savings on an average cost Inventory Trending Monitor for these plants would be $510,000 for backfit plants and $274,000 for forward fit.

The indicated magnitude of savings by deleting the qualification requirements appears to warrant serious consideration for this option. As noted in previous discussion, the cost reduction may be somewhat overestimated in some cases because the estimators assumed that the use of organic cabling and non-qualifiable connectors would be acceptable for this option. In fact, the actual environmental limits for which some existing signal channel designs could be expected to function are unknown and regulatory decisions regarding this design option would be difficult. Adoption of Option 3 for ICC instrumentation while continuing to require full environmental qualification for other accident monitoring instrumentation would also appear to be inconsistent logic. Unless the design requirements are specified in much more detail with design guidance (e.g., specify acceptable materials and components), it is also likely that regulatory actions regarding Option 3 will be inconsistent. Finally, the two generic designs which have been reviewed and are acceptable to the staff

(Westinghouse and CE designs) are being environmentally qualified by testing which is complete or in advanced stages. A change in requirements at this time would benefit those systems not yet reviewed (e.g., B&W and independent designs) and penalize those designs and installations which were accomplished in a good faith effort to comply with the NUREG-0737 schedule requirements. The large number of inventory trend monitoring systems in an advanced status of design and implementation would also significantly limit the total savings to be realized by adopting this option.

4.3.3 Delete Single Failure Design Requirements (Option 4)

This option (see Table 3) would result in an average backfit cost reduction of 30% for the estimated plants. The savings on an average cost Inventory Trending Monitor for the estimated plants would be $953,000 for backfit and $292,000 (16%) for forward fit.

The single failure design increases the reliability and availability of the instrumentation. If an instrumentation channel must be operable while the plant is operating (presently recommended technical specifications), it is believed that the potential impact of Option 4 on plant down time is too great to permit an ultimate cost benefit by selection of design Option 4.

4.3.4 Delete Class 1E Power Source (Option 5)

The cost estimates (see Table 4) indicate little or no savings associated with design Option 5. The average cost reduction of 2 percent would amount to a backfit savings of $37,000 for an average cost Inventory Trend Monitor for estimated plants.

The reactor coolant pump power or current monitors are relatively low in cost. Indicated savings of $25,000 or less for the various design options do not appear to justify special design requirements for this instrumentation. It would be more appropriate to maintain design requirements for this instrumentation which are consistent with the requirements for other ICC instrumentation.

As was the case for the CET system (Section 4.1.4), the small savings associated with Option 5 do not appear to justify the increased vulnerability of the inventory trend monitor to a loss of power.

4.4 Inventory Trending with RCS Pumps On

For those plants employing the CE or Westinghouse inventory trending systems, no additional equipment is required for tracking inventory with pumps on. For plants which do not have an inventory tracking capability with pumps on, pump power or pump current monitors have been proposed to accomplish this function. Cost estimates for the system (see Table 4) range from $200,000 to $280,000.

The average savings associated with design options 2 thru 5 respectively are 1%, 1%, 8% and 0% for backfit, and 10%, 20%, 50% and 0% for forward fit.

4.5 Conclusions

A summary of cost data for all of the ICC instrumentation and percent savings for the design options is provided in Table 5. The total average cost for upgrading of existing instrumentation and provision of additional instrumentation in accordance with NUREG-0737 (II.F.2) ICC instrumentation requirements is $5,889,000 for backfit and $3,632,000 for forward fit of estimated plants. The respective cost reductions associated with backfit for design Options 2, 3, 4, and 5 are 11%, 23%, 26% and 2%.

Based on the data and the preceding discussion of this section, the conclusions regarding each of the design options follows:

(1) Option 2, delete seismic design requirements, would result in total average savings of $650,000 (11%) for backfit plants and $327,000 (9%) for forward fit plants.

The capability of the ICC instrumentation to monitor accidents associated with seismic events would be adversely affected by this option.

Some older plants have special problems associated with the seismic design and installation which may result in a significantly higher fraction of costs associated with the seismic design. Unique plant specific seismic problems resulting in a significantly greater impact should be considered on backfit plants.

(2) Option 3, delete environmental qualification requirements (except seismic), would result in total average savings of $1,360,000 (23%) for backfit plants and $508,000 (14%) for forward fit plants.

The savings associated with this design option are significant. However, it is believed that some of the savings are due to the use of lower quality materials and equipment which may not meet the intent of the specification.

Approval of this design option for some or all of the ICC instrumentation components, even though it is a substantial contributor to costs, does not appear to be workable unless in conjunction with its adoption, acceptability standards are specified in some detail. Any relief from this requirement would need to be consistent with the EQ Rule. The benefits associated with the qualification of this instrumentation to assure its availability when subjected to anticipated accident environments appear to be more substantial than the cost saving associated with deleting the EQ requirement.

(3) Option 4, delete single failure requirements, would result in a total average savings of $1,500,000 (26%) for backfit plants and $800,000 (22%) for forward fit plants.

Although this design option would result in the largest cost reduction of the options considered, it would sacrifice reliability and availability of the ICC instrumentation system. If one channel of instrumentation is always required to be operable while the plant is operating, it is expected that potential plant down-time would not make this design option cost effective.

(4) Option 5, delete Class 1E power source requirements, would result in total average savings of $136,000 (2%) for backfit plants and $145,000 (4%) for forward fit plants.

The cost impact of this design requirement is relatively small and the requirement is believed to be justified in terms of the availability of ICC instrumentation when needed.

5.0 RECOMMENDATIONS

Based on the industry recommendations provided in Section 2.0, the cost/benefit considerations of Section 4.0, and the current status of ICC instrumentation with respect to NUREG-0737 (II.F.2) design requirements, staff recommendations to the CRGR follow:

(1) Design requirements specified for Item II.F.2 of NUREG-0737 should remain applicable for all forward fit plants (i.e. instrumentation sub-systems which were incomplete with respect to procurement and installation on January 1, 1982). However, some NTOLs requiring major revision of installed equipment should be classified as backfit.

(2) NUREG-0737 design specifications should be considered as design guidelines for backfit plants (i.e., instrumentation sub-systems which were complete with respect to procurement and installation on January 1, 1982). The staff should maintain flexibility

to approve deviations consistent with design Options 2 or 3 for individual plants when justified by the operating utility. An acceptable justification would be a plant specific cost/benefit analysis indicating plant unique problems resulting in signifcantly greater impact of seismic and environmental qualification requirements on ICC instrumentation costs than was concluded in Section 4.0 of this report.

(3) No further change in NUREG-0737 design requirements is recommended.

Table 1 : Core Exit Thermocouples

COST / BENIFIT STUDY FOR ICC INSTRUMENTATION

COST OF DESIGN OPTIONS ($/PLANT) (x$1,000)

Instrumentation	Option / Source	1 (C)	2 (S)	3 (S)	4 (S)	5 (S)
Core Exit Thermocouples	B&W	Proprietary				
	B&WOG	1,200 To 1,500	24 To 27	50 To 44	24	0 To 16
	CE	Proprietary				
	CEOG	6,280	13	61	27	2
	WOG BF	3,700	5	16	16	0
	WOG FF	860	25	16	16	0
	AIF (1) BF	957	10	1	21	0
	AIF (1) FF	551	10	3	28	0
	AIF (2) BF	648	34	5	45	5
	AIF (2) FF	578	33	4	45	4
	AIF (3) BF	1,200	8	50	0	0
	AIF (3) FF	1,200	8	17	17	0
	AIF (4) BF	2,750	2	2	16	0
	AIF (5) FF	551	30	3	42	0
	AIF (5) FF	1,250	12	12	20	4
	AIF (6) FF	1,000	15	15	25	10
	AIF (6) FF	1,250	12	12	20	8
Over All Average Saving $\frac{\Sigma C_i S_i}{\Sigma C_i}$ (%)	BF	2,148	14	35	21	3
	FF	948	15	12	22	5

NOTE : C – Cost ; S – Saving in % ; BF – Backfit ; FF – Forward Fit
% – Percent Saving Compared With Option 1

DESIGN OPTIONS

1. Reference Design - meets NUREG-0737 design requirements.
2. Delete all seismic design requirements from reference design.
3. Delete environmental qualification requirements, except seismic, from reference design.°
4. Delete single failure design requirements (redundancy) from reference design.
5. Delete Class IE power source requirement from reference design.

Table 2 : Subcooling Margin Monitor

COST / BENIFIT STUDY
FOR ICC INSTRUMENTATION

COST OF DESIGN OPTIONS ($/PLANT) (x$1,000)

Instrumentation	Option / Source			1 (C)	2 (S)	3 (S)	4 (S)	5 (S)
Subcooling Margin Monitor	B&W			Proprietary				
	B&WOG							
	CE			Proprietary				
	CEOG			500	20	60	40	0
	WOG		BF	500	5	16	16	0
	WOG		FF	100	5	16	16	0
	AIF	(1)	BF					
	AIF	(1)	FF					
	AIF	(2)	BF	231	33	5	45	5
	AIF	(2)	FF	208	33	5	45	5
	AIF	(3)	BF					
	AIF	(3)	FF	195	5	18	18	18
	AIF	(4)	BF					
	AIF	(5)	FF	195	21	18	18	18
	AIF	(5)	FF	1,750	14	14	29	9
	AIF	(6)	FF	1,500	17	17	33	10
	AIF	(6)	FF					
Over All Average Saving $\frac{\Sigma C_i S_i}{\Sigma C_i}$ (%)			BF	325	19	30	30	2
			FF	658	16	15	30	10

NOTE: C – Cost ; S – Saving in % ; BF – Backfit ; FF – Forward Fit
% – Percent Saving Compared With Option 1

DESIGN OPTIONS

1. Reference Design - meets NUREG-0737 design requirements.
2. Delete all seismic design requirements from reference design.
3. Delete environmental qualification requirements, except seismic, from reference design.*
4. Delete single failure design requirements (redundancy) from reference design.
5. Delete Class IE power source requirement from reference design.

Table 3 : Inventory Trending With RCS Pumps Off

COST / BENIFIT STUDY FOR ICC INSTRUMENTATION

COST OF DESIGN OPTIONS ($/PLANT) (x$1,000)

Instrumentation	Option / Source			1 (C)	2 (S)	3 (S)	4 (S)	5 (S)
Inventory Trending With RCS Pumps off	B&W			Proprietary				
	B&WOG			1,950	0	13	49	0
	CE			Proprietary				
	CEOG			5,280	13	42	30	2
	WOG		BF	3,900	2	2	20	0
			FF	878	10	20	50	0
	AIF	(1)	BF	3602	10	20	5	10
			FF	3694 TO 2972	0 0	22 3	6 8	0 0
		(2)	BF	2450	34	5	45	5
			FF					
		(3)	BF	2200	14	18	36	0
			FF	1,470	7	20	20	5
		(4)	BF	4,500	0	11	49	0
		(5)	FF	195	21	18	18	18
			FF	1750	14	14	29	9
		(6)	FF					
			FF					
Over All Average Saving $\frac{\Sigma C_i S_i}{\Sigma C_i}$ (%)			BF	3,176	9	16	30	2
			FF	1,826	4	15	16	2

NOTE : C – Cost ; S – Saving in % ; BF – Backfit ; FF – Forward Fit

% – Percent Saving Compared With Option 1

DESIGN OPTIONS

1. Reference Design – meets NUREG-0737 design requirements.
2. Delete all seismic design requirements from reference design.
3. Delete environmental qualification requirements, except seismic, from reference design.*
4. Delete single failure design requirements (redundancy) from reference design.
5. Delete Class IE power source requirement from reference design.

Table 4 : Inventory Trending with RCS Pumps On

COST / BENIFIT STUDY
FOR ICC INSTRUMENTATION

COST OF DESIGN OPTIONS ($/PLANT) (x$1,000)

Instrumentation	Source		Option 1 (C)	2 (S)	3 (S)	4 (S)	5 (S)
Inventory Trending With RCS Pumps On	B&W		Proprietary				
	B&WOG						
	CE		Proprietary				
	CEOG						
	WOG	BF	200	2	2	20	0
		FF	200	10	20	50	0
	AIF (1)	BF					
		FF					
	AIF (2)	BF					
		FF					
	AIF (3)	BF					
		FF					
	AIF (4)	BF					
	AIF (5)	FF					
		FF					
	AIF (6)	FF					
		FF					
Over All Average Saving $= \frac{\Sigma C_i S_i}{\Sigma C_i}$ (%)		BF	240	1	1	8	0
		FF	200	10	20	50	0

NOTE: C – Cost ; S – Saving in % ; BF – Backfit ; FF – Forward Fit
% – Percent Saving Compared With Option 1

DESIGN OPTIONS

1. Reference Design – meets NUREG-0737 design requirements.
2. Delete all seismic design requirements from reference design.
3. Delete environmental qualification requirements, except seismic, from reference design.*
4. Delete single failure design requirements (redundancy) from reference design.
5. Delete Class IE power source requirement from reference design.

Table 5 : Over All Average Saving

COST / BENIFIT STUDY
FOR ICC INSTRUMENTATION

COST OF DESIGN OPTIONS ($/PLANT) (x$1,000)

Instrumentation	Option / Fit Status	1 (C)	2 (S)	3 (S)	4 (S)	5 (S)	Range (C)
Core Exit Thermocouples	BF	2,148	14	35	21	3	648 To 6,280
	FF	948	15	12	22	5	551 To 1,250
Subcooling Margin Monitor	BF	325	19	30	30	2	70 To 500
	FF	658	16	15	30	10	100 To 1,750
Inventory Trending With RCS Pumps Off	BF	3,176	9	16	30	2	1,530 To 5,280
	FF	1826	4	15	16	2	195 To 3,694
Inventory Trending With RCS Pumps on	BF	240	1	1	8	0	200 To 280
	FF	200	10	20	50	0	200
Over All ICC Instrumentation	BF	5,889	11	23	26	2	2,448 To 12340
	FF	3,632	9	14	22	4	1,046 To 6,894

NOTE : C - Cost ; S - Saving in % ; BF - Backfit ; FF - Forward Fit

%- Over All Average saving $\left(\frac{\Sigma C_i S_i}{\Sigma C_i}\right)$ Compared with Option 1

DESIGN OPTIONS

1. Reference Design - meets NUREG-0737 design requirements.
2. Delete all seismic design requirements from reference design.
3. Delete environmental qualification requirements, except seismic, from reference design.*
4. Delete single failure design requirements (redundancy) from reference design.
5. Delete Class IE power source requirement from reference design.

APPENDIX A

REQUEST FOR ADDITIONAL INFORMATION ON FAILURE
MODE AND EFFECT ANALYSIS AND COST/BENEFIT
STUDY FOR ICC INSTRUMENTATION

A.1 "Westinghouse Reactor Vessel Level Instrumentation System Using Differential Pressure", A letter to O. D. Kingsley (WOG) from D. M. Crutchfield (NRC), April 30, 1982.

A.2 "CE Reactor Vessel Level Measurements System Using Heated Junction Thermocouple", A letter to K. P. Baskin (CE OG) from D. M. Crutchfield (NRC), April 30, 1982.

A.3 A letter to F. Cadek (Westinghouse) from R. J. Mattson (NRC) April 1, 1982.

A.4 "Minutes of CRGR Meeting No. 11" A memorandum for W. J. Dircks (NRC) from V. Stello, Jr., (Chairman of CRGR), April 2, 1982.

A.5 Summary of Westinghouse Owners' Group Responses to Concerns of the Failure Mode and Effects Analysis for Westinghouse d/p System.

A.6 Summary of Combustion Engineering Owners' Group Response to Concerns of CE Heated Junction Thermocouple Responses to an Upper Head Break, a Large Break LOCA, and a Failure Mode and Effects Analysis.

A.7 A letter to T. Huang (NRC) from J. L. Anderson (ORNL), May 27, 1982.

A.8 A letter to T. Huang (NRC) from R. L. Anderson (ORNL), June 16, 1982.

A.1

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

April 30, 1982

Mr. O.D. Kingsley
Westinghouse Owners Group
Alabama Power Company
Post Office Box 2641
Flintridge Building
Birmingham, Alabama 35291

Dear Mr. Kingsley:

SUBJECT: WESTINGHOUSE REACTOR VESSEL LEVEL INSTRUMENTATION SYSTEM USING DIFFERENTIAL PRESSURE

REFERENCE: TMI Item II.F.2

We have reviewed the Westinghouse reactor vessel level instrumentation using differential pressure and found that additional information is required.

Accordingly, please respond to the enclosed request, which has been previously discussed with you by May 15, 1982.

This request for information is within the purview of OMB Clearance Number 3150-0065.

Sincerely,

Dennis M. Crutchfield

Dennis M. Crutchfield, Chief
Operating Reactors Branch #5
Division of Licensing

Enclosure:
Request for Additional Information

REQUEST FOR ADDITIONAL INFORMATION ON
WESTINGHOUSE REACTOR VESSEL LEVEL INSTRUMENTATION
SYSTEM USING DIFFERENTIAL PRESSURE

Describe the effects of failure of the following components of the differential pressure level measurement system with respect to measurement system response, information presented to the operator and effects on recovery from an abnormal transient.

A. Connections to Primary System

1. Break or leak in each (single failure) connecting line between reactor vessel and sensor.
2. Failure of sensor diaphragm.
3. Failure of limit switches on sensor.
4. Sticking of limit switches on sensor.
5. Sticking of diaphragm (caused by perhaps over-pressurization in one direction).
6. Plugging of impulse lines or ports.

B. Connecting Lines Between Sensor and Hydraulic Isolators

1. Break or leak in each (single failure) connecting line.
2. Failure of RTD on connecting lines.
3. Plugging of connecting lines.

C. Hydraulic Isolator

1. Failure of diaphragm.
2. Failure of overpressurization limit switches.
3. Break or leak in connecting lines to dP transducer.
4. Break or leak in valves in connecting lines to dP tranducer.

D. DP Transducer

1. Failure of diaphragm.
2. Plugging of connecting lines.
3. Failure of transmitter (electronic).
4. Improper connection of signal or power lines to transducer.
5. Failure of connectors at transducer.
6. Failure of signal or power cables.
7. Failure of valves in connecting lines to dP transducer.

E. Controls and Signal Processing

1. Failure of microprocessor
   a. Complete
   b. Partial (eg., failure of some memory locations)
2. Failure of signal isolator.
3. Sticking of analog meter indicators.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

April 30, 1982

Docket No.: See Attached Listing
LS05-82-

Mr. Ken P. Baskin, Chairman
CE Owners Group
Southern California Edison Company
Post Office Box 800
2244 Walnut Grove Avenue
Rosemead, California 91770

Dear Mr. Baskin:

SUBJECT: CE REACTOR VESSEL LEVEL MEASUREMENT SYSTEM USING HEATED JUNCTION THERMOCOUPLE

REFERENCE: TMI Item II.F.2

We have reviewed the CE reactor vessel level measurement system using heated junction thermocouples and found that additional information is required.

Accordingly, please respond to the enclosed request which has been previously discussed with you by May 15, 1982.

This request for information is within the purview of OMB Clearance Number 3150-0065.

Sincerely,

Dennis M. Crutchfield

Dennis M. Crutchfield, Chief
Operating Reactors Branch #5
Division of Licensing

Enclosure:
Request for Additional
Information

cc w/enclosure:
See next page

REQUEST FOR ADDITIONAL INFORMATION ON CE REACTOR VESSEL LEVEL MEASUREMENT SYSTEM USING HEATED JUNCTION THERMOCOUPLES

1. Provide an analysis of the response (with the reactor coolant pumps running) of the heated junction thermocouple level measurement system (a) with the full length separator tube, and (b) with the split separator tube in the System 80 plants. Also discuss the instructions to the operator for interpretation of the indications.

2. Provide an analysis of the response of the heated junction thermocouple level measurement system with a break in the upper head (a) with the full length separator tube and (b) with the split separator tube in the System 80 plants. Also discuss the instructions to the operator for interpretation of the indications.

3. Provide an analysis of the response of the heated junction thermocouple level measurement system after a large break LOCA. In particular how will the level inside that separator tube compare with the level outside, taking into account the drain rate of the separator tube. What instructions will be provided the operator for interpretation of the indicators?

4. Describe the effects of failure of the following components of the heated junction thermocouple level measurement system with respect to measurement system response, information presented to the operator, and effects on recovery from an abnormal transient.

A. Sensor

1) Single thermocouple failure in a single sensor. The thermocouple is assumed to fail by a break in at least one thermoelement that would result in an open circuit.

a. Would the automatic checking procedure detect the fault before the QSPDS continued to record data?
b. What would happen to the differential output?

2) Heater failure in a single sensor. The heater is assumed to fail by a break in the heater element that would result in an open circuit.

a. Would the automatic checking procedure detect the fault before the QSPDS continued to record data?
b. What would be the effect on the other heaters in the same string?

3) Assume a rupture in the sensor sheath so that coolant is admitted into the sensor.

a. Would the automatic checking procedure detect the fault before the QSPDS continued to record data?
b. What would be the effect on the heater in the affected area, and other heaters in the same string?

B. Probe

1) Reactor vessel seal failure.

C. Cables

1) Assume failure of connector.

a. Complete failure of connector.
b. Partial failure (only some of the connections fail).

2) Severed cable.

3) Wet connector.

4) Incorrect wiring at connectors (or any other location inside containment).

A common error in large installations is the incorrect wiring of the thermocouple extension cables by connection of the Alumel extension lead to the Chromel thermoelement et cetera. Under stable containment conditions this could produce an offset. If the temperature of the containment were to rise, much larger temperature errors could result. This situation should be analyzed for the effect on both the thermocouple signals from the individual thermocouples and the differential signals.

D. Control Circuit

1) If the heater supply is designed for fast response, rapid fluctuations in the control signal can induce oscillations in the heater supply output. This in turn could cause heater failure by overheating or fatigue.

A.3

Phillips

APR 1 1982

Mr. Fred Cadek
Westinghouse Electric Corporation
Box 355
Pittsburgh, Pennsylvania 15230

Dear Mr. Cadek:

As you know, the NRC is presently reviewing its requirements concerning Inadequate Core Cooling (ICC) instrumentation. Design requirements are specified in Section II.F.2 of NUREG-0737, and in Appendix B of that document. In the course of our review, it has come to our attention that some aspects of our design requirements, e.g., the seismic qualification for core exit thermocouples, may impose a cost burden for some plants which is not justifiable in terms of the potential need and benefits derived from that aspect of the design.

Please provide us with cost data which show the costs associated with the various design alternatives for inadequate core cooling instrumentation described in the table below. This data will be used by the NRC for the purpose of a cost/benefit evaluation to determine if some of our existing requirements can be relaxed while still meeting the safety objectives of the ICC instrumentation system.

The table identifies five design options which we want to consider. In addition, we would appreciate industry comments and cost estimates concerning a sixth option, which would be your recommendation for an optimum design based on value/impact considerations. This may, of course, be identical to one of the identified five options. Estimates for both forward fit (new plant design) and backfit (new plant design modifications and operating reactor design upgrade) are desired and should be clearly identified.

For purposes of your cost estimate, you should assume that the NRC will require all of the instrumentation identified in the first column of Table I as a minimum ICC instrumentation system. Assume that the current designs of the Westinghouse RVLIS system and the Combustion Engineering Heated Junction Thermocouple (HJTC) system meet the inventory monitoring requirements with reactor coolant pumps off. You can also assume for these cost estimates that other differential pressure (d/p) measurement concepts are acceptable in principle for inventory monitoring with the pumps off if they include pressure sensing taps from the reactor vessel head to the lowest level of the hot leg and from the top of the hot leg candy cane for B&W designed reactors. Assume also that the Westinghouse d/p monitor and the Combustion Engineering HJTC system provide adequate inventory trending with pumps on. Other concepts which are acceptable in principle for trending the primary coolant liquid inventory content or void with pumps on are based on pump power or pump current measurements.

For all design options, assume that NRC will require high Quality Assurance standards for design, construction and installation in conformance with Appendix B 10 CFR Part 50. Any option recommended by you should be described and cost/benefit considerations should be discussed. The benefit of a design option should be assessed in terms of its contribution to ICC monitoring system reliability, capability to avoid plant down time for maintenance, need for multiple channels to verify the information during an accident or to prevent plant shutdown due to ICC system unavailability, performance under expected environmental conditions, protection against ambiguity because of failure under harsh environmental conditions, and special problems associated with separation requirements for safety grade and non-safety grade instrumentation. If you recommend design requirements other than those associated with the traditional safety grade of equipment, please be explicit. For example if a power source need not be Class 1E, we would still expect it to be of some specified high reliability and battery backed if momentary interruption is not tolerable.

We request that you provide us with your cost estimates by April 19, 1982. Thank you for your cooperation.

Sincerely,

/S/

Roger J. Mattson, Director
Division of Systems Integration

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IDENTICAL LETTERS TO:

Mr. O. Kingsley, Chairman
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APC
600 N. 18th St.
Birmingham, Alabama 35291

Mr. K. P. Baskin, Chairman
CE Owners Group
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Lynchburg, Virginia 24505

*SEE PREVIOUS CONCURRENCE

OFFICE	DSI:CPB	DSI:CPB	DSI:AD:CPS	DSI:DIR			
SURNAME	*LPhillips	*CBerlinger	*LRubenstein	RMATTSON			
DATE				4/ 1 /82			

TABLE I

COST/BENEFIT STUDY

FOR ICC INSTRUMENTATION

Cost of Design Options ($/Plant)

Instumentation	1	2	3	4	5	6
Core Exit Thermocouples						
Subcooling Margin Monitor						
Inventory Trending with RCS Pumps Off						
Inventory Trending with RCS Pumps On						

DESIGN OPTIONS

1. Reference Design - meets NUREG-0737 design requirements.
2. Delete all seismic design requirements from reference design.
3. Delete environmental qualification requirements, except seismic, from reference design.*
4. Delete single failure design requirements (redundancy) from reference design.
5. Delete Class 1E power source requirement from reference design.
6. Respondents' Recommended Design (Describe differences relative to Option 1)

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* In this option, when we say "delete environmental qualification", we mean that there need be no qualification by testing under expected accident conditions, but the equipment would be expected, by design or analysis, to survive and function under design basis accident conditions.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 2 1982

MEMORANDUM FOR: William J. Dircks
Executive Director for Operations

FROM: Victor Stello, Jr., Chairman
Committee to Review Generic Requirements

SUBJECT: MINUTES OF CRGR MEETING NO. 11

The Committee to Review Generic Requirements met on Wednesday, March 24, 1982, from 1-5 pm. Attendance at the meeting is shown in the Enclosure. The following matters were considered:

1. Mr. Guzy of RES presented the proposed Regulatory Guide SC78-4, "Qualification and Acceptance Tests for Snubbers Used in Systems Important to Safety." The Committee requested that further information be provided on the questions below in order that the Guide can be reconsidered at a future meeting.

   (a) In view of the potential $20-40 million cost that could result from implementing the proposed Reg. Guide,

      - what safety problems would be corrected by this Guide that warrant these costs?
      - are there less costly alternatives?
      - to what degree would snubber problems still persist because of improper installation, maintenance or operational problems?

   (b) What is the expected increase in occupational exposure associated with implementing the proposed Reg. Guide?

   (c) Are there less prescriptive alternatives than Appendix A, which appear to be a purchase specification for snubbers, to achieve the goal of improved snubber performance?

   (d) Why and to what extent is 10 CFR 50 Appendix B, Quality Assurance, required by the proposed Reg. Guide?

   (e) What is the safety basis for the proposed implementation plan?

   (f) What is the design basis for the acceptance criteria in the proposed Reg. Guide (for example, water hammer loads)?

   (g) Why is rule language, "shall" and "shall not," used in the proposed Reg. Guide?

2. Dr. Mattson of NRR presented a status summary on TMI Action Plan Task II.F.2, "Instrumentation for Detection of Inadequate Core Cooling." The discussion centered on the instrumentation systems proposed by PWR vendors for measuring reactor coolant level. The Committee did not reach a decision on a recommendation concerning the proposed systems pending further information from NRR on total ICC system costs and certain other questions regarding how the system is to be used by the operators. Nonetheless, the Committee agreed with the general approach outlined by NRR.

The impetus for considering the need for additional instrumentation to detect inadequate core cooling came from the experience of TMI. One of the most important lessons from that accident was that the operators required more information on the status of core cooling during an accident than was available in the control room at the time. This realization led to early actions by NRC to require the installation of Subcool Monitors (SM) in PWR control rooms and to upgrade the number and quality of core-exit thermocouples (TC) in PWRs. Even with this added instrumentation, however, there remained, during a small LOCA, a period of time after the system reaches saturated conditions (indicated by SM) but before the core has boiled dry (indicated by TC) when the operators have insufficient information to track the inventory of coolant in the vessel and primary system. It was to fill this gap that NRR has required extensive further studies by the industry to determine whether additional instrumentation could be provided to monitor the status of core cooling.

Based on the discussions with NRR and review of extensive material prepared by NRR and industry, the Committee reached the following preliminary conclusions:

(a) Additional instrumentation to detect ICC would be highly desirable to complement the current package of Subcool Monitors and thermocouples.

(b) Rather than requiring an unambiguous indication of water level in the vessel (which is probably not possible), it is probably sufficient to require only a void indication or inventory tracking system to aid the operators in the period between saturation and core dryout.

(c) A differential pressure system and a heated junction thermocouple system appear to be acceptable methods for void indication or tracking inventory.

(d) Other means, such as reactor coolant pump electrical current suggested by the LOFT project, may also be beneficial for tracking coolant density (and hence inventory) under pumps on condition.

(e) The instruments comprising the ICC package should be viewed as a whole, not individually, and clear guidelines should be developed on the use and limitations of each instrument in the ICC package.

(f) If a void indication or inventory tracking system is utilized, it should not be made operational until after appropriate Emergency Operating Procedure Guidelines for the overall ICC package are reviewed and approved. The system should be factored into the task analysis portion of the Detailed Control Room Design Review by the licensee, and operators should be trained in its operation and limitations.

(g) The cost-benefit assessment should be based on consideration of the costs of the overall package, including the need for redundancy and qualification requirements.

The Committee requested that this topic be reviewed again after receipt of further information from NRR.

Victor Stello, Jr., Chairman
Committee to Review Generic Requirements

Enclosure: List of Attendees

cc: CRGR Members
Office Directors
G. Cunningham, ELD
Commission (5)
Regional Administrators

A-5 Summary of Westinghouse Owners' Group Responses to Concerns of the Failure Mode and Effects Analysis for Westinghouse DP Systems

For the Westinghouse DP system, the WOG has responded to the concerns (A.1 in Appendix A) about the effects on the measurement system response of the failure of critical components, including a break or leak in connecting lines or valves; plugging of connecting lines or ports; failure of the sensor diaphragm, the RTD on connecting lines or the overpressurization limit switches for hydraulic isolators; failure of connectors at the transmitter, failure of the signal or power cables and electronic transmitters for the DP transducer and failure of the processor (complete or partial).

The details of FMEA responses from WOG are summarized as follows:

(1) All connections to the reactor coolant system are orificed so that a break is not classified as a LOCA, and the charging pumps can make up the leakage. The increased charging flow would be one confirming indication of leakage.

Indications for the three standard system instrument ranges during (1) normal operation, (2) with a break in a single connecting line in the upper location, and (3) with a break in a single connecting line in the lower location are presented in the following table:

INSTRUMENT	UPPER RANGE	NARROW RANGE	WIDE RANGE
Normal indication, pumps on	Offscale Lo	Offscale Hi	100%
Normal indications, pumps off	100%	100%	33%
Upper connection location	Vessel Top	Vessel Top	Vessel Top
Indication with break	Offscale Hi	Offscale Hi	Offscale Hi
Lower connection location	Hot Leg	Vessel Bottom	Vessel Bottom
Indication with break	Offscale Lo	Offscale Lo	Offscale Lo

Except for a break in a hot leg connection with pumps on, at least one meter would provide a clear indication of a break in any connection. If the common vessel top or bottom connection failed, both trains of connected instruments would indicate the failure. Additional confirmation of a break would be provided by checking the volumetric displacements at the hydraulic isolator gauges in the containment penetration area.

If a leak developed in a connection, the pressure drop of the leakage flow would move the indicators in the same direction as a break. Since the instrument spans are relatively small, very little leakage flow would be required to produce an offscale indication.

In most cases, vessel level indications would not be available when a connection breaks or leaks, in which case the core exit thermocouples would provide the necessary indication for an ICC condition.

In the system provided for plants equipped with UHI, the upper connection for the narrow range and wide range instruments is on the hot leg. The indications with a break in a connection would be the same as for the standard system indications in the table above.

(2) Since the lines are cleaned, tested, filled and then sealed, and the ports are in low velocity, subcooled water areas, there is no mechanism that would cause plugging.

(3) The hydraulic isolator is provided with two diaphragms in series, with a water-filled volume between the diaphragms. A crack or pinhole leak in one diaphragm would have no affect on the system performance. If both diaphragms leaked, slow volume displacements could pass through the isolator without moving the diaphragms and the needle on the gauge, and the limit switch would not respond to a downstream leak. A large downstream leak, such as a break in the

capillary line, would most likely cause a displacement of the isolator diaphragms and closure of the internal valve, isolating the leak.

Periodic surveillance of the hydraulic isolator gauges would detect an abnormal (neutral) displacement resulting from a leak in both diaphragms.

(4) Switches operated by the hydraulic isolator displacement will provide an indication of an abnormal displacement of ± 0.4 cu. in. from neutral. Larger displacements are required to close either internal valve. If a switch failed, the operator would be advised immediately of an abnormal volume displacement. System operation would not be affected until the displacement actually closed a valve, and the dp transmitter would then respond. Periodic surveillance of the hydraulic isolator gauges would detect a displacement at or beyond the switch setpoint.

(5) Like the hydraulic isolators, the DP transducer is provided with two diaphragms in series, so there would be no effect on the system unless both diaphragms leaked. The dp transmitters are provided with over-range protection, i.e. internal valves that close when the transmitters move offscale. Therefore, no large differential pressure would be applied to the diaphragm to cause a failure.

(6) The electronic transmitter is basically a loop current regulating device consisting of a current amplifier, regulator, power supply and load. Each transmitter loop circuit is independent so that failure in the loop circuit only affects its corresponding main control board display. The display of the second train is not affected. The operator can detect a difference of the same two readings (Train A and Train B) and can institute troubleshooting procedures to determine the faulty loop circuit during plant operations. During refueling/maintenance outage, a calibration check is performed so that any malfunction can be identified and corrected.

(7) Model 752 Barton dp Transmitter uses a terminal block for hard wire connection for the incoming leads and for the connection to the amplifier card. The terminal block is designed with melamine separation between connection studs to ensure that electrical separation is maintained.

A loose terminal connection can result in no output or erratic output of the dp transmitter and can be detected by differences in the remote display readings by the operator and troubleshooting action can be initiated.

(8) Failure of the incoming cable to a dp transmitter will result in no output or erratic output of the dp transmitter resulting in differences between readings in the main control board displays which can be detected by the operator.

(9) Complete failure of the processor in the microprocessor RVLIS (Reactor Vessel Level Instrumentation System) is detected by a "deadman circuit" which, during normal operation, is reset by the processor at the completion of each update cycle.

At the end of each display update cycle, the processor program performs a sequence of tests to determine whether the program memory (PROM) has any altered bits and whether the read-write memory (RAM) has any faults. If faults are detected, an error message is displayed on both the local and remote digital displays and the caution level annunicator relay is actuated.

In cases of processor failure, both partial and complete, the operator is alerted that the system is malfunctioning by the actuation of the caution level annunicator. Level information is not displayed by a malfunctioning system so that incorrect data is not presented.

ORNL has reviewed WOG's responses to concerns of the FMEA for the Westinghouse DP System and found them to be satisfactory. ORNL has also found that the comprehensive nature of these responses show evidence of careful consideration of these factors during the design phase of the system.

A-6 Summary of Combustion Engineering Owners' Group Responses to Concerns of CE Heated Junction Thermocouple Responses to an Upper Head Break or a Large Break LOCA and a Failure Mode and Effects Analysis

For the Combustion Engineering HJTC System, the CEOG has responded to concerns (A.2 in Appendix A) about the effects of an upper head break or a large break LOCA on measurement system response and has provided an analysis of the failure mode for each critical component, including thermocouple sensor, heated junction thermocouple probe, cables, and control circuits.

The details fo the CEOG submittal are summarized as follows:

(1) For a postulated break in the upper head, the principal question is whether hold-up of two-phase mixture inside the separator tube might cool the HJTC sensors resulting in an indication of an unchanged water level while the water inventory outside the probe could decrease. Test results incidate that this is not the case. The separator tube provides a true indication of the collapsed level even under these conditions.

A top blowdown was simulated in the Phase II tests of the HJTC probe assembly. With the test vessel completely filled with water and at a pressure of about 1800 psig, a valve at the top of the vessel was opened. This initiated a blowdown from the top of the test vessel at a rate of about 10 psi/sec, which is about 10 times faster than during a small break. Three HJTC sensors were located about 54 inches apart at the top, middle and bottom of the separator tube which was placed inside the test vessel.

The differential temperature for the top and middle HJTC sensors increased in sequence after the blowdown valve was opened, indicating that the water level in the separator tube was receding from the top down in the same manner the water inventory outside the separator tube was receding. The test ended before the bottom sensor was uncovered. This test showed that a two-phase mixture that could keep the HJTC sensors cooled did not flow up the separator tube as a result of the top blowdown.

Based on present information, the response of the HJTC level measurement system to a break in the upper head is expected to be generally similar to the response for a break elsewhere in the primary system. Thus, the operator would not need any special instructions for this case.

(2) The HJTC System is intended to provide the operator with information that he can use in mitigating the consequences of a transient which produces a void in the reactor vessel. The blowdown portion of a large break LOCA occurs approximately during the first half minute of the transient and proceeds much too fast for the operator to take any action. Thus, the HJTC System is not designed to measure the collapsed water level during this time period. It will, however, measure the collapsed level during the reflood portion of a large break which proceeds at a much slower rate than the blowdown.

It is not expected that any substantial water hold-up will occur in the separator tube during a large break. There is one set of eight 9/32 inch diameter holes at both the bottom and at the top of the separator tube. This provides a flow area for drainage that is approximately equal to the inside area of the separator tube. The total volume inside a full-length separator tube is only about 0.05 ft^3. Thus, the flow holes in the separator tube pose no significant restriction to the escape of flashing steam or draining water. During a rapid depressurization like in a large LOCA blowdown, the water inside the separator tube is expected to flash and escape from the separator tube in the same time period as the water in the surrounding region flashes and is discharged from the primary system.

Phase II test results show that the water level inside the separator tube lags the level outside the separator by less than four inches for an outside drain rate of 5 in/sec. This agrees with calculations that have been performed for conservatively high drain rates outside the separator. Thus, the separator tube is capable of draining fast enough so that the level inside the tube is very close to the level outside the tube.

For a large break LOCA, it will be recommended that the operator disregard the indicated level until after the initial blowdown period is over and the reactor coolant system pressure has become stable. This blowdown period will last for only a short time during the initial part of the transient.

(3) The A/D circuitry uses a "flying capacitor" input isolation technique for the thermocouple (TC) inputs to the microprocessor. If a thermocouple circuit opens, an open TC detention circuit drives the capacitor to a full scale input voltage, which is detected in the microprocessor as a fault condition. The open thermocouple circuit has a fixed time constant which will take a few microprocessor cycles to drive the capacitor up to a full scale value and be detected. After detection that the thermocouple is failed, the microprocessor (μP) provides a fault indication at the operator display and disregards the TC input in all future calculations.

If the chromel wire from the heated junction breaks, the differential (ΔT) output will continue to increase until the microprocessor detects a full scale heated junction temperature voltage reading. Then the thermocouple input will be recognized as faulty and disregarded.

If the chromel wire from the unheated junction breaks, the differential output will continue to decrease and eventually go negative. This continues until the P detects an unheated junction voltage reaching the top of scale. The thermocouple input will be disregarded.

For a break in the alumel wire, common to the heated and unheated junctions, the differential output will remain essentially constant but will drift up as both heated and unheated inputs are driven to the top of scale value. The processor detects and alarms the open TC and will disregard its use.

(4) The heater controller used in the RVLMS is a time-modulated controller. When the control signal from the processor calls for full power, the controller delivers 100% power, 100% of the time. If the processor calls for 50% power (for example), the controller delivers 100% power for only one half of its duty cycle. The particular controllers utilized in the Heated Junction Thermocouple System have a duty cycle of 0.8 seconds. The sensor heaters and the controllers are sized such that full power is applied to all heaters during all normal operating conditions (i.e., when the sensors are covered, or at high pressure). In the event that uncovery occurs, the heater controllers may be called upon to reduce power to the heaters depending on the absolute temperature of any heated thermocouple or on the differential temperature of any sensor.

The heater control scheme uses a proportional control law in which the microprocessor heater control signal goes from 100% to 0% over a temperature input range of 200°F. This shallow slope prevents large changes in power from being applied for small changes in input temperature. Some heater power cycling has been observed to occur because of the sampling rate of the microprocessor.

During Phase III tests of the system, the fluctuations of the heated junction temperature have been observed to be relatively small, on the order of 10°F. These fluctuations are insignificant when compared to the temperature swings which result from uncovery or quenching of the sensor, and do not contribute significantly to heater fatigue.

ORNL has reviewed the CEOG response to concerns about an upper head break, a large break LOCA and the FMEA for the CE heated junction thermocouple system and has found the submittal to be satisfactory. ORNL has also concluded that the comprehensive nature of these responses is indicative of CE's careful consideration of these factors during the design phase of the system.

OAK RIDGE NATIONAL LABORATORY
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UNION CARBIDE CORPORATION
NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

May 27, 1982

Dr. T. Huang
Core Performance Branch
Division of Systems Integration
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Huang:

We have reviewed the "Westinghouse Response to NRC Staff Request for Additional Information on Westinghouse Reactor Vessel Level Instrumentation System Using Differential Pressure", dated May 14, 1982.

We find that the Westinghouse and the Westinghouse Owner's Group responses to the request for additional information related to failure modes and effects analysis are satisfactory. The comprehensive nature of these responses show evidence of careful consideration of these factors during the design phase of the system.

Sincerely,

John L. Anderson

J. L. Anderson
Reactor Systems Design & Evaluation Group
Instrumentation & Controls Division

JLA/r

cc: R. L. Anderson
C. N. Miller

OAK RIDGE NATIONAL LABORATORY

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POST OFFICE BOX X

OAK RIDGE, TENNESSEE 37830

June 16, 1982

Dr. T. Huang
Core Performance Branch
Division of Systems Integration
Office of Nuclear Reactor Regulation
Washington, DC 20555

Dear Dr. Huang:

We have reviewed C-E's responses to our most recent set of questions on the heated junction thermocouple system - including the Failure Mode and Effects Analysis. We find these responses to be satisfactory. We find that the responses of Combustion Engineering and the Combustion Engineering Owner's Group to the requests for additional information related to failure modes and effects analysis are satisfactory. The comprehensive nature of these responses is indicative of C-E's careful consideration of these factors during the design phase of the system. With the satisfactory resolution of these questions, we know of no further open issues related to the generic heated junction thermocouple level measurement system.

Very truly yours,

Richard L. Anderson

RLA:wmm

cc: J. L. Anderson
G. N. Miller
File-NoRC