STATUS SUMMARY

TMI ACTION PLAN II.F.2

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

OCTOBER 1982

PREPARED FOR:
BRIEFING OF CRGR

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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

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* 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.

design requirements. Although cost data provided by the vendors indicate that the procurement costs for these sytems are comparable, installation costs vary considerably. The staff review of the B&W proposed inventory trending 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 the CE Qualified Safety Parameter Display System (QSPDS 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 CE Qualified Safety Parameter Display System (QSPDS) for a single plant. We have conservatively allocated about 2/3 of this cost to the CET system and 1/3 to the inventory trending system, even though the QSPDS services many other instrumentation systems. 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 equipment 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.

3.3 Occupational Exposure Costs

The industry has provided data on the estimated personnel exposure for both upgrading the core exit thermocouples and installing the reactor vessel inventory trend monitor to meet Item II.F.2 of NUREG-0737 requirements. The personnel exposure data vary depending on the extent of installation labor required within a radiation field to accomplish the modifications needed for a specific plant, and depending on the dose rate in the region of interest, which is partially dependent on the number of operating cycles completed. For example, 1.5 man-rems for upgrading 65 cable-thermocouple connectors at a dose rate of 300 mr/hr and 40 man-rems for upgrading 56 cables and connectors were estimated by Westinghouse and Combustion Engineering, respectively, and a range from 20 man-rems to 50 man-rems is expected for personnel exposure during backfit installation of the reactor vessel inventory trend monitor. In addition, nine man-rems exposure was experienced for upgrading 10 cable-thermocouple connectors at a Combustion Engineering plant with a number of years of operation and 10 man-rems exposure was experienced by SMUD for the core exit thermocouple upgrading required for the Rancho Seco plant.

The staff has also reviewed information provided for San Onofre Unit 2 and has calculated a best estimate of approximately 60 man-rems of personnel exposure for upgrading 56 core exit thermocouple cables and connectors, and installing two Heated Junction Thermocouple probe assemblies. However, these modifications are in excess of those required to conform with NUREG-0737 (e.g., only 16 core exit thermocouples must be upgraded).

Based on the available information provided by the industry, the staff has concluded that occupational exposures estimated for the total backfit installation to meet NUREG-0737 requirements for Item II.F.2 ranged from 5 to 60 man-rems per plant with 20 to 30 man-rems believed to be the typical case.

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 accidents involving multiple failures beyond the design basis. Failure to design the instrumentation to withstand seismic events of SSE magnitude may significantly reduce the probability of having an operable ICC instrumentation system for a an accident or transient event in conjuction with a large earthquake. 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. Additionally, elimination of the seismic design requirements for this instrument package would make it appear to be inferior to other accident monitoring instrumentation which must be designed to function following a Safe Shutdown Earthquake (SSE) in order to conform with Regulatory Guide 1.97. This would tend to undermine operation confidence in the system.

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 and reliability 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. It is expected that a harsh environment would exist within containment under many circumstances when this instrumentation would be needed.

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. In particular, CET information should remain available for events involving loss of off-site power.

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 shows 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. In addition, the single failure design aids the operator in diagnosing instrument failures which result in faulty information from one display train. For the Westinghouse differential pressure system, multiple trains and displays are inherent to the design logic for system diagnostics.

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 vulner-ability 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-07.7 (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%.

There is a stong incentive to maintain all of the design requirements specified in NUREG-0737 (i.e., Option 1), which are consistent with safety grade design requirements normally associated with other accident monitoring instrumentation specified in Regulatory Guide 1.97. Less stringent general design requirements for this specific instrumentation would tend to diminish its importance in the view point of the operator, and would reduce his confidence in the reliability of information displayed during an accident. Based on the data and the preceding discussion of this section, conclusions regarding each of the other design options follow:

(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 function following a seismic event would be adversely affected by this option. This would degrade plant safety for cases where plant operation continues after an earthquake.

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 mounting problems which have an unusual cost impact should be considered for exceptions if requested for 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. Capability of the instruments to function properly would be threatened under many

ICC conditions which lead to a harsh environment within containment. 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.

In addition, the reliability would be degraded by a loss of diagnostic capability inherent in multiple channels of display information. The Westinghouse design relies on multiple display information for diagnostics associated with their Failure Mode and Effects Analysis. The diagnostic capability inherent in multiple channels is also important to building operator confidence in the system and reduces the likelihood of operator misdiagnosis which could lead to error in actions taken to control transient events of moderate frequency.

(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. The availability of ICC instrumentation is believed to be particularly important during loss of heat sink conditions and slow moving transient events (with time available for operator intervention) frequently associated with loss of off-site power.

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 accep-table 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	Source		1 (C)	2 (S)	3 (S)	4 (S)	5 (S)
Core Exit Thermocouples	B&W		Proprietary				
	B&W OG		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	3700	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)	[illegible]	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. [illegible]

Table 2 : Subcooling Margin Monitor

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)
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	Source			Option 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	4500	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. [illegible]

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					
		(2)	BF					
			FF					
		(3)	BF					
			FF					
		(4)	BF					
		(5)	FF					
			FF					
		(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 [illegible]

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	5889	11	23	26	2	2,448 To 12,340
	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.

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

A.1

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

8205130001

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.