ENCLOSURE 1

SAFETY EVALUATION REPORT
GENERIC LETTER 83-28, ITEM 4.5.3 REACTOR TRIP SYSTEM RELIABILITY FOR ALL DOMESTIC OPERATING REACTORS

1.0 INTRODUCTION

On February 25, 1983, both of the scram circuit breakers at Unit 1 of the Salem Nuclear Power Plant failed to open upon an automatic reactor trip signal from the reactor protection system (RPS). This incident was terminated manually by the operator about 30 seconds after the initiation of the automatic trip signal. The failure of the circuit breakers was determined to be related to the sticking of the undervoltage trip attachment. Prior to this incident, on February 22, 1983, at Unit 1 of the Salem Nuclear Power Plant, an automatic trip signal was generated based on steam generator low-low level during plant startup. In this case, the reactor was tripped manually by the operator almost coincidentally with the automatic trip.

Following these incidents, on February 28, 1983, the NRC Executive Director for Operations (EDO), directed the staff to investigate and report on the generic implications of these occurrences at Unit 1 of the Salem Nuclear Power Plant. The results of the staff's inquiry into the generic implications of the Salem Unit 1 incidents are reported in NUREG-1000, "Generic Implications of the ATWS Events at the Salem Nuclear Power Plant". As a result of this investigation, the Commission (NRC) requested (by Generic Letter 83-28 dated July 8, 1983) all licensees of operating reactors, applicants for an operating license, and holders of construction permits to respond to generic issues raised by the analyses of these two ATWS events.

The licensees were required by Generic Letter 83-28, Item 4.5.3 to confirm that on-line functional testing of the reactor trip system (RTS), including independent testing of the diverse trip features, was being performed at all plants.

Existing intervals for on-line functional testing required by Technical Specifications were to be reviewed to determine if the test intervals were adequate for achieving high RTS availability when accounting for considerations such as: (1) uncertainties in component failure rates; (2) uncertainties in common mode failure rates; (3) reduced redundancy during testing; (4) operator error during testing; and (5) component "wear-out" caused by the testing.

2.0 DISCUSSION

The NRC's contractor, Idaho National Engineering Laboratory (INEL), reviewed the licensee Owners Group availability analyses and evaluated the adequacy of the existing test intervals, with a consideration of the above five items, for all plants. The results of this review are reported in detail in EGG-NTA-8341, "A Review of Reactor Trip System Availability Analyses for Generic Letter 83-28, Item 4.5.3 Resolution," dated March 1989 and summarized in this report. The results of our evaluation of Item 4.5.3 and our review of EGG-NTA-8341 are presented below.

The Babcock & Wilcox (B&W), Combustion Engineering (CE), General Electric (GE), and Westinghouse (W) Owners Groups have submitted topical reports either in response to GL 83-28, Item 4.5.3 or to provide a basis for requesting Technical Specification changes to extend RTS surveillance test intervals (STI). The owners groups' analyses addressed the adequacy of the existing intervals for on-line functional testing of the RTS, with the considerations required by Item 4.5.3, by quantitatively estimating the unavailability of the RTS. These analyses found that the RTS was very reliable and that the unavailability was dominated by common cause failure and human error.

The ability to accurately estimate unavailability for very reliable systems was considered extensively in NUREG-0460, "Anticipated Transients Without Scram for Light Water Reactors", and the ATWS rulemaking. The uncertainties of such estimates are large, because the systems are highly reliable, very little experience exists to support the estimates, and common cause failure probabilities are difficult to estimate. Therefore, we believe that the RTS unavailability estimates in these studies, while useful for evaluating test intervals, must be used with caution.

NUREG-0460 also states that for systems with low failure probability, such as the RTS, common mode failures tend to predominate, and, for a number of reasons, additional testing will not appreciably lower RTS unavailability. First, testing more frequently than weekly is generally impractical, and even so the increased testing could at best lower the failure probability by less than a factor of four compared to monthly testing. Secondly, increased testing could possibly increase the probability of a common mode failure through increased stress on the system. Finally, not all potential failures are detectable by testing. In summary, NUREG-0460 provides additional justification to demonstrate that the current monthly test intervals are adequate to maintain high RTS availability.

3.0 CONCLUSION

All four vendors' topical reports have shown the currently configured RTS to be highly reliable with the current monthly test intervals. Our contractor has reviewed these analyses and performed independent estimates of their own which conclude that the current test intervals provide high reliability. In addition, the analyses in NUREG-0460 have shown that for a number of reasons, more frequent testing than monthly will not appreciably lower the estimates of failure probability.

Based on our review of the Owners Group topical reports, our contractor's independent analysis, and the findings noted in NUREG-0460, we conclude that the existing intervals, as recommended in the topical reports, for on-line functional testing are consistent with achieving high RTS availability at all operating reactors.

EGG-NTA-8341
March 1989

Idaho National Engineering Laboratory

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TECHNICAL EVALUATION REPORT

A REVIEW OF REACTOR TRIP SYSTEM AVAILABILITY ANALYSES FOR GENERIC LETTER 83-28, ITEM 4.5.3, RESOLUTION

David P. Mackowiak
John A. Schroeder

EG&G IDAHO

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TECHNICAL EVALUATION REPORT: A REVIEW OF REACTOR TRIP SYSTEM AVAILABILITY ANALYSES FOR GENERIC LETTER 83-28, ITEM 4.5.3, RESOLUTION

David P. Mackowiak
John A. Schroeder

EG&G Idaho, Inc.
Idaho Falls Idaho 83415

FIN D6001: Evaluation of Conformance to Generic Letter 83-28 for ORs (Project 2)

SUMMARY

The two anticipated transient without scram (ATWS) events at the Salem Nuclear Power Plant in February of 1983, focused the attention of the Nuclear Regulatory Commission (NRC) on the generic implications of ATWS events. The NRC then published Generic Letter 83-28 (GL 83-28) which listed the actions the NRC required of all licensees holding operating licenses and others with respect to assuring the reliability of the Reactor Protection System (RPS). GL 83-28, Item 4.5.3, required licensees to demonstrate by review that the current on-line functional testing intervals are consistent with achieving high reactor trip system (RTS) availability. The licensees responded to the GL 83-28, Item 4.5.3, requirements as Owners Groups with reports either in direct response to Item 4.5.3, or with a technical basis for requesting extensions to the surveillance test intervals (STIs) that generally included the Item 4.5.3 required reviews.

The NRC's Instrumentation and Control Systems Branch (ICSB), Office of Nuclear Reactor Regulation (NRR), requested the Idaho National Engineering Laboratory (INEL) to review the licensee availability analyses and evaluate the overall adequacy of the existing test intervals. INEL review results showing general compliance with Item 4.5.3 will provide the NRC with a basis to close out Item 4.5.3 without further review.

For the review, the INEL defined three acceptance criteria, reviewed the licensees topical reports, contractor review reports, and NRC safety evaluations, and determined the adequacy of the analyses and the RTS availability estimates with regard to the review criteria.

The INEL review criteria to determine the licensees' Item 4.5.3 compliance were, (1) the five areas of concern of Item 4.5.3, (2) the analyses' plant applicability, and (3) the NRC's RTS electrical unavailability base case estimates from the ATWS Rulemaking Paper, SECY-83-293.

ACRONYMS

ATWS	Anticipated Transient Without Scram
B&W	Babcock & Wilcox
BNL	Brookhaven National Laboratory
CE	Combustion Engineering
GE	General Electric
HTGR	High-Temperature Gas-Cooled Reactor
ICSB	Instrumentation and Control Systems Branch
INEL	Idaho National Engineering Laboratory
LWR	Light Water Reactor
NFSC	Nuclear Facility Safety Committee
NRC	Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation
PORC	Plant Operations Review Committee
PSC	Public Service Company of Colorado
PWR	Pressurized Water Reactor
RSSMAP	Reactor Safety Study Methodology Applications Program
RPS	Reactor Protection System
RTS	Reactor Trip System
SER	Safety Evaluation Report
STI	Surveillance Test Interval
TER	Technical Evaluation Report
W	Westinghouse

TECHNICAL EVALUATION REPORT: A REVIEW OF REACTOR TRIP SYSTEM AVAILABILITY ANALYSES FOR GENERIC LETTER 83-28, ITEM 4.5.3 RESOLUTION

1. INTRODUCTION

1.1 Historical Background

In February of 1983, two events occurred at the Salem Nuclear Generating Station that focused Nuclear Regulatory Commission (NRC) attention on the generic implications of anticipated transient without scram (ATWS) events.

First, on February 22, during startup of Unit 1 an automatic trip signal generated as a result of a steam generator low-low level failed to cause a reactor scram. The reactor was tripped manually by an operator almost coincidentally with the automatic trip signal, so the fact that the automatic trip had failed to cause a scram went unnoticed.

Three days later on February 25, both of the scram breakers at Unit 1 failed to open on an automatic reactor protection system (RPS) scram signal. The operators took action to control this second ATWS and succeeded in terminating the incident in about 30 seconds. Subsequent investigation related the failure of the Unit 1 RPS to cause a scram to sticking of the undervoltage trip attachment in the scram circuit breakers.

As a result of these events the NRC Executive Director for Operations directed the staff to undertake three related activities: (1) an evaluation of when and under what conditions the Salem plants would be allowed to restart; (2) a fact finding report of the events at Salem 1 and the circumstances leading to them; and (3) a report on the generic implications of these events.

To address (3) above an interoffice, interdisciplinary group was formed including members from the Office of Nuclear Reactor Regulation's

The Babcock & Wilcox (B&W), Combustion Engineering (CE), General Electric (GE), and Westinghouse (W) Owners Groups have submitted topical reports either in response to GL 83-28, Item 4.5.3[3,4] or to provide a basis for requesting RTS surveillance test interval (STI) extensions.[5,6,7,8,9,10,11] In general, the owners groups' analyses were not done on a plant specific basis. Instead, the analyses addressed a particular class of reactor trip system and then discussed the applicability of the analysis to specific product lines. The NRC reviewed these reports for, among other things, their applicability to GL 83-28, Item 4.5.3 and summarized their findings in Safety Evaluation Reports[12,13] (SERs).

1.2 Review Purpose

This report documents a review of the Owners Groups' topical reports, the NRC SERs, and other analyses done at the Idaho National Engineering Laboratory (INEL) by personnel in the NRC Risk Analysis Unit of EG&G Idaho, Inc. The INEL conducted the review at the request of the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Instrumentation and Control Systems Branch (ICSB). The review was performed to determine if the Owners Groups' analyses demonstrated high RTS availability for the current test intervals, if the analyses included the five areas of concern from GL 83-28, and if all of the plants were covered by the analyses. The results of the review, if all plants are shown to be covered by an adequate analysis, would provide the NRC with a basis for closing out GL 83-28, Item 4.5.3, for all U.S. commercial nuclear reactors without further review.

The body of this report presents the review and its findings with regard to the stated objectives. Section 2 describes the criteria used in the review to determine the adequacy of the analyses. The review methodology is discussed in Section 3. Section 4 presents the review results. The review conclusions are given in Section 5.

The estimates from the NRC ATWS analysis provide a framework with which to consider the topical report analyses estimates. The numerical estimates in the SECY-83-293 for the four vendors combined with the five areas of concern from GL 83-28, Item 4.5.3, form the criteria used for this review to determine if the vendors' analyses and estimates met the requirements of Item 4.5.3.

4. REVIEW RESULTS

This section summarizes the results of the INEL review of the vendors' analyses with regard to the five areas of concern and plant applicability. The vendors' estimates of RTS availability are compared to the review availability criteria. Also, some insights concerning RTS availability, gained from an examination of PWS importance measures from selected PRAs, are examined.

4.1 B&W Plants

The issues of GL 83-28, Item 4.5.3, were addressed by the B&W Owners Group and the results were submitted to the NRC by the individual utilities in their responses to GL 83-28. Topical Report BAW-10167 (Reference 5) was submitted to the NRC to provide a technical basis for increasing the on-line STIs and allowed outage times (AOTs) for B&W RTS instrument strings. The analysis presented in BAW-10167 was built upon the previous analysis done to address the GL 83-28, Item 4.5.3 issues. However, some information that was resolved in the generic letter analysis was not repeated in the subsequent Topical Report because it was not relevant to the proposed Technical Specification changes. To make BAW-10167 applicable to both GL 83-28, Item 4.5.3 and STI/AOT issues, the Owners Group submitted BAW-10167, Supplement 1 (Reference 6), to the NRC. Supplement 1 completed the B&W analysis by addressing all remaining Item 4.5.3 issues. The BAW-10167 and Supplement 1 analyses included the implementation of the automatic shunt trip on the reactor trip circuit breakers as required by GL 83-28, Item 4.3.

The INEL has previously reviewed the BAW-10167 and Supplement 1 analyses and documented the review in a TER, EGG-REQ-7718 (Reference 15). For the TER, sensitivity studies which included all of the Item 4.5.3 areas of concern were conducted on the RTS models. The sensitivity study results showed the models to be insensitive to variations in the failure rates associated with the Item 4.5.3 areas of concern.

failure rates. The insensitivity to increased component failure rates along with the CE analysis results showing trip circuit breaker common cause failures to be the major contributor to RTS unavailability provides a a basis for this review to conclude that RTS test-induced component wear-out is not an issue at CE reactors.

The INEL reviewed CEN-327 and the TER and determined that the CE analyses have adequately covered all five areas of concern or they have been shown not to contribute to RTS unavailability and that all currently operating CE reactors are included.

4.3 GE Plants

Licensees with GE reactors responded to the GL 83-28, Item 4.5.3 requirements as the BWR Owners' Group by submitting NEDO-30844 (Reference 4) to the NRC. The RTS availability analysis specifically included the five areas of concern and covered both generic relay and solid-state RTS designs which includes all currently operating BWRs. GE stated that the relay RPS configurations for BWR plants have the same primary design features. Therefore, the generic relay RTS models used in NEDO-30844 do not differ significantly from the specific BWR plants. GE used the Clinton 1 drawings for the solid-state RTS models. Since Clinton 1 is currently the only GE plant with a solid state RTS, no plant unique analysis is necessary.

The BWR Owners' Group also submitted NEDO-30851P (Reference 8) to the NRC. The analysis in this second report used the base case results from NEDO-30844 to establish a basis for requesting revisions to the current Technical Specifications for the RTS. The INEL had previously reviewed NEDO-30844 and NEDO-30851P with regard to both Item 4.5.3 and STI extension acceptability and documented the review in a TER, EGG-EA-7105 (Reference 17). Due to insufficient information, the INEL review could not complete the solid-state RTS review and accepted only the relay RTS analysis results. The NRC reviewed the topical reports and the TER and

3. Unavailability of components due to unscheduled maintenance

4. Unavailability of components due to human error

5. Unavailability of components due to common cause failure.

While the W analysis did not directly include any sensitivity studies concerning these five areas, the component unavailabilities were increased as the test interval length increased. The STI analysis results showed a factor of 3 to 5 increase in the RTS unavailability estimates for the longer test interval. Two conservatisms exist in the models that are relevant: first, no credit was taken for early failures that would be detected and, second, no credit was taken for the diversity inherent in the W RTS design. These two conservatisms, had they been included in the model, would cause the increase in the RTS unavailability estimates to be smaller than the observed factors.

Test-induced component wear-out was not addressed in any manner in the W RTS analysis. However, the RTS analyses done by the other vendors, References 3, 4 and 6, specifically investigated the effects of this issue on RTS unavailability. Despite the differences among the other vendors' RTS designs, they all found the effects of test induced component wear-out on RTS unavailability to be insignificant. Based on the other vendors' analyses, the INEL concluded that the effects of test-induced component wear-out on W RTS unavailability would also be insignificant. Therefore, the INEL considers all W plants to be covered by adequate analyses.

4.5 Quantitative Review of Vendors' RTS Availabilities

So far, only the adequacy of the vendors' analyses has been discussed. No determination has been made of the acceptability of the numerical estimates from the various RTS availability analyses. In this section, the INEL review considers the four Owners Groups' RTS availability estimates to determine if they are indeed indicative of "high availability."

TABLE 1. COMPARISON OF VENDOR AND NRC RTS UNAVAILABILITY ESTIMATES[a]

Vendor	Vendor RTS Unavailability Estimates (Failures/Demand)	NRC RTS Unavailability Estimates[b] (Failures/Demand)
B&W		
Davis Bessie Model	1E-10[c]	3E-5[d]
Oconee Class Model	1E-6[c]	3E-5[d]
CE		
Plant Class 1	2E-7[e]	2E-5
Plant Class 2	3E-6[e]	2E-5
Plant Class 3	3E-6[e]	2E-5
Plant Class 4	2E-6[e]	2E-5
GE		
Relay Plants	3E-6[f]	2E-5
Solid-state Plants	3E-6[f]	2E-5
W		
Relay Plants	5E-5[g]	5E-5[d]
Solid-state Plants	5E-5[g]	5E-5[d]

a. All estimates are rounded off to one significant digit.

b. From Reference 14, Table A-1, base case RTS electrical unavailability estimates.

c. From Reference 5, base case.

d. Includes automatic shunt trip on the reactor trip circuit breakers.

e. From Reference 7, Tables 4.1-1, 4.2-2, 4.1-3, and 4.1-4, respectively; base case test interval, high pressurizer pressure unavailability estimate.

f. From Reference 4.

g. From Reference 19, solid state RTS base case. Applied to relay-plants based on similarity of design (see Reference 11, Section 3.2.2 and 3.2.3).

From these responses, the INEL concluded that Fort St. Vrain has conducted the review required by GL 8[illegible]-28, Item 4.5.3, and that the NRC considers the PSC and NRC reviews adequate to meet the Item 4.5.3 requirements.

6. REFERENCES

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3. Combustion Engineering, Reactor Protection System Test Interval Evaluation, Task 486, CE NPSD-277, December 1984.

4. S. Visweswaran et al., BWR Owners' Group Response to NRC Generic Letter 83-28, Item 4.5.3, NEDO-30844, January 1985.

5. R. S. Enzinna et al., Justification for Increasing the Reactor Trip System On-line Test Interval, BAW-10167, May 1986.

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12. U.S. Nuclear Regulatory Commission Memorandum, G. C. Lainas to E. J. Butcher, Acceptance for Referencing of General Electric Company (GE) Topical Reports NEDO-30844, "BWR Owners' Group Response to NRC Generic Letter 83-28," and NEDO-30851P, "Technical Specification Improvement Analyses for BWR Reactor Protection System," April 28, 1986.

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EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, ID 83415

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The Idaho National Engineering Laboratory (INEL) conducted a technical review of the commercial nuclear reactor licensees' responses to the requirements of the Nuclear Regulatory Commission's (NRC's) Generic Letter 83-28 (GL 83-28), Item 4.5.3. The results of this review, if all plants are shown to be covered by an adequate analysis, will provide the NRC staff with a basis to close out this issue with no further review. The licensees, as the four vendors' Owners' Groups, submitted analyses to the NRC either directly in response to GL 83-28, Item 4.5.3, or to provide a basis for requesting changes to the Technical Specifications (TSs) that would extend the Reactor Protection System (RPS) surveillance test intervals (STIs). To conduct the review, the INEL defined three criteria to determine the adequacy, the plant applicability, and the acceptability of the results. The INEL examined the Owners Groups' reports to determine if the analyses and results met the established criteria. Fort St. Vrain's responses to Item 4.5.3 were also reviewed. The INEL review results show that all licensees of currently operating commercial nuclear reactors have adequately demonstrated that their current on-line RPS test intervals meet the requirements of GL 83-28, Item 4.5.3.

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