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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION RELATING TO AMENDMENT 17 GENERAL ELECTRIC TOPICAL REPORT NEDE-24011-P "GENERAL ELECTRIC STANDARD APPLICATION FOR REACTOR FUEL"

1.0 INTRODUCTION

In a letter of August 15, 1986 from T. A. Pickens, Chairman of the BWR Owners Group (BWROG), an Amendment 17 to the General Electric (GE) Topical Report NEDE-24011-P (GESTAR II) was proposed (Ref. 1). Attached was a BWROG and GE report, "Modification to the Requirements for Control Rod Drop Accident Mitigating Systems", along with proposed changes to GESTAR II and sample changes to Technical Specifications relating to the mitigating systems.

This submittal is a request to (1) eliminate the required use of the rod sequence control system (RSCS) on those reactors having such a system, while retaining the rod worth minimizer (RWM) to provide backup to the operator for control rod pattern control, and (2) lower the setpoint for turn off of the RWM (or RSCS) to 10 percent of full power from its current 20 percent level.

The report indicates that the primary justifications for these proposals are that (1) the RSCS is redundant to the RWM and is therefore not needed to mitigate the control rod drop accident (RDA), and (2) existing calculations demonstrate that the RDA is not of significant concern above 10 percent power and therefore a mitigation system is not needed for higher power level operation.

The proposal also indicates that additional justifications or incentives for the RSCS removal are provided by: (a) Existing NRC sponsored RDA analysis methodology improvements show significantly less severe peak fuel enthalpy for a given dropped rod reactivity worth; (b) an existing NRC probability study demonstrates an extremely low probability for an event exceeding fuel damage criteria; and (c) RSCS elimination will reduce operation complexity and startup-shutdown times and will permit quicker power reduction in emergency conditions such as ATWS, particularly for Group Notch RSCS (GNRSCS) reactors.

2.0 BACKGROUND

The RSCS is a hard wired (as opposed to a computer controlled) system designed to monitor and block when necessary operator control rod selection, withdrawal and insertion actions, and thus assist in preventing significant control rod pattern errors which could lead to a control rod with a high reactivity worth (if dropped). A significant pattern error is one of several abnormal events all of which must occur to have a RDA which might exceed fuel energy density limit criteria for the event. It was designed only for possible mitigation of the RDA and is active only during low power operation (currently generally less than 20 percent power) when a RDA might be of significance. It provides rod blocks on detection of a significant pattern error. It does not prevent a RDA. A similar pattern control function is also performed by the RWM, a computer controlled system. All reactors having a RSCS also have a RWM. 9/88

BWRs beginning with Oyster Creek have all had a RWM for RDA rod pattern control. (BWR6s do not.) The RSCS is the result of NRC staff and consultant reviews in the early 1970s of GE RDA analysis methodology. These reviews concluded that the dropped rod and scram reactivity insertion rates being used were not suitably conservative. The corrected and improved, but still very conservative, consultant and GE calculations immediately following these reviews indicated that previously calculated margins to the acceptance criteria for peak fuel enthalpy in a licensing RDA event analysis (assuming a maximum non-error rod worth) had been significantly reduced. They also indicated that, unlike previous conclusions, single errors in rod patterns could, in some cases, lead to rod worths for which a RDA could exceed limits. This was particularly likely to be the case for the part length gadolinium controlled cores which were then being introduced, and for cores in which axial burnup is accounted for in the analysis.

These changes in analysis led to a NRC staff interest in improved prevention of high reactivity worth error rods. There was at the time also staff dissatisfaction with the adequacy of the RWM and its use (to be discussed in Section 3). Interaction between the staff and GE led to the development by GE of the RSCS and its required installation for reactors coming on line. (There was also a tightening of Technical Specifications (TS) for the RWM on operating reactors.) The near term BWR4 reactors (except Vermont Yankee), a total of 13 reactors, received the Group Notch version of the RSCS (GNRSCS), and later BWR4 and 5 reactors, a total of 9, an improved RSCS not requiring the group notch restriction, but rather using a Banked Position Withdrawal Sequence (BPWS) described in Reference 4. (Group notch operation requires rod group bank steps of only a single notch for control rod densities less than 50 percent, an this requires considerable time for that segment of startup or shutdown operations, and it can not enforce the improved BPWS patterns for rod densities above 50 percent. BPWS operation uses considerably fewer group steps and is much less complex.) All of the RSCS reactors retain a RWM as a parallel system. BWR6s have a pattern control system not involving the RSCS or RWM. All BWR 2 and 3 reactors plus Vermont Yankee, 10 reactors, have only a RWM.

Subsequent to the adoption of the RSCS for new reactors, the question of backfit of a RSCS for operating reactors arose. To answer this an extensive probability study of the likelihood of exceeding peak enthalpy limits as a result of a RDA was carried out by the staff. It concluded that there was no need for backfit of a RSCS (and none was done, Reference 5) and no evident need for it on new reactors (but the requirement was none-the-less continued). This probability study is presented in an appendix in Reference 2 which is a general discussion by the staff for the ACRS of RDA problems and solutions. (This reference may also be used as general background material.) The ACRS reviewed the probability study, along with other RDA methodology, during its examination of BWR RDA problems under the ACRS Generic Item II A 2 (later designation II A 1), and indicated it considered the problems to be resolved in its 1977 status report (Reference 7). The probability study will be further discussed in Section 3.

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Also, subsequent to the RDA analysis methods studies and changes which led to the RSCS requirements, the methodologies have been further investigated and improved by staff consultants at Brookhaven National Laboratory (BNL) in areas of three dimensional and thermal feedback modeling (see for example Reference 3). The results of calculations with these methods indicate significantly lower peak fuel enthalpy values for a given rod worth compared to GE calculations using the standard, more approximate and conservative methodology in use during the RSCS development time frame (and used ever since). While there is some uncertainty with the improved methods about some aspects of the thermal-hydraulic feedback (see Section 3.2) even a conservative interpretation of the calculations indicates that maximum single error RDA events are not likely to exceed criteria.

3.0 EVALUATION

As indicated in the background discussion, there were at the time (about 1973) RSCS requirements were promulgated by the staff a number of "perceived" problems or unknown factors relating to the RDA which were of significance to the decision. The perceived situation leading to the RSCS may be summarized as follows:

1. With the GE methodology and the (then) newly required reactivity insertion and scram rates, rod worths achievable without pattern error produced RDA analyses results approaching enthalpy limits. Even minor pattern errors, therefore, could lead to exceeding limits, and therefore any pattern error should be (redundantly) prevented.

2. The RWM was not effectively required by TS and was poorly maintained or improved and frequently bypassed and thus provided no significant protection. Furthermore, computer related protection systems were (then) inherently distrusted. Second operator substitution for the RWM was used routinely and was apparently providing minimal protection since procedures and quality control were frequently poor.

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3. There existed no (trusted) study of the probability of exceeding enthalpy limits as a result of a RDA and improved calculational methods providing more realistic modeling of an event were only in early stages of development and use. There was therefore nothing to alleviate concerns arising from the above perceptions.

Since that time information about these areas has been significantly expanded or modified, leading to a revised perception of the problem area.

3.1 Probability Study

A primary factor in the evaluation of the present proposal is the staff probability study which was performed to provide a basis for examining RSCS backfit requirements on then operating reactors. That study (Ref. 2) carried out (in 1975) an independent analysis of the probabilities, individual and combined, of the multiple events that must occur in order that a RDA exceed the staff acceptance criteria of 280 cal/gm in the peak fuel pellet.

To have the possibility of exceeding limits a RDA must occur, and must occur with reactor conditions and related parameters within a narrow range of a much broader set of possible conditions. The event must involve all of the following: (1) a drive-blade disconnect, (2) which is not discovered before rod drop occurs, (3) the blade must stick, (4) and not be discovered, (5) the sticking must occur in upper 1/6 of core, (6) the drive must be lowered at least 2-3 feet, (7) an incorrect rod pattern must have been selected and pulled and, (8) the error not detected, (9) the error must directly involve the dropped rod and, (10) the error must provide an unusually high worth for that rod, (11) the rod blade must unstick and drop, (12) the drop must occur at low power (less than 10%), (13) it must occur when the relevant overall rod pattern is such as to enhance the rod worth (a small fraction of pattern development time).

The study determined conservative probabilities for these occurrences and their combination. It concluded that "a reasonable (and quite possibly conservative) estimate of the probability of having a RDA exceeding 280 cal/gm is about 10^{-12} per reactor year. This is a large margin to an acceptance criterion of 10^{-7} per reactor year, and allows for considerable uncertainty in the input information or unforeseen interactions among elements of the analysis."

It may be noted that about 10 times the number of reactor years included in that study have accumulated since the probabilities were developed. There has been no occurance of a rod drop or even a combination of any two of the necessary initiating events listed above (e.g., 1, 3, 7). The increased statistical data indicate that the individual probabilities used in the study have remained about the same or decreased, and the combination would be significantly smaller.

This study was done and its conclusions were reached assuming that neither the RSCS or RWM were in use. It thus concluded that backfit of a RSCS on an operating reactor was not needed. It also concluded that the study did not appear to demand the extra probability decrease which could be achieved from use of the RWM. It nevertheless recommended that it be retained and that TS be such as to assure a reasonable degree of operability.

3.2 RDA Analysis Methodology

The probability study was performed assuming results from the GE RDA calculation methodology. In the years since, BNL has continued studies of RDA methodology and results have indicated a substantial reduction in enthalpy for a given rod worth as a result of better geometrical and moderator reactivity feedback modeling. The results from Reference 3, for example, for "zero" power RDA events indicate very low peak enthalpies (less than about 130 cal/gm for maximum rod worths (about 1.5% delta k) assuming no pattern errors, and less than 200 cal/gm for maximum rod worths (about 2.5% delta k) which might

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exist assuming maximum single error patterns. These enthalpies are for a large degree of moderator subcooling. The calculations give much lower enthalpies for lower subcooling margin conditions usually found in relevant BWR operating conditions. However, these very low values are currently uncertain because of uncertainties about the degree of superheating rather than voiding which might occur in the moderator under the very rapid transient heating conditions. However, a conservative conclusion from these results (using moderate and large subcooling to mock up delayed voiding) is that there is a large likelihood that error patterns would not lead to a rod worth which could exceed limits in a "zero" power RDA. The study also clearly showed that in the 10 percent power range (and above) peak enthalpies would always be well below limits.

The probability level of exceeding the 280 cal/gm fuel enthalpy limit as determined in the 1975 study could be further reduced by giving credit for current improved analysis methods and results and for the use of BPWS rod patterns which reduce the expected maximum rod worths.

3.3 RWM Operation

At the time the RSCS requirements were being developed the staff also was changing the TS requirements for the RWM in the operating reactors without an RSCS. Whereas previously the TS had generally permitted RWM operation to be replaced by a second operator check off system without further restriction, the TS were altered to require more mandatory use of the RWM. Various forms of these changes were developed by the staff project managers, but they were equivalent in requiring at least partial active use of the RWM for low power operation throughout the reactor cycle. This appears to have resulted in greatly improving the RWM availability and use, and reducing the routine use of the second operator. It demonstrated that the RWM could be a reliable system for providing any necessary Limiting Condition of Operation (LCO) surveillance. (Note that the RSCS is a LCO surveillance system.) Furthermore in the intervening time, computer controlled LCO surveillance and even protection systems have become recognized as acceptable by the staff.

Examples are the Combustion Engineering COLSS and CPC surveillance and protection systems, and the GE process computer system which is a recognized acceptable system for power density LCO monitoring in BWRs. A more direct example of RWM acceptance can be noted in the approval (Ref. 6) of BPWS generic RDA statistical analysis credit for GNRSCS reactors electing BPWS for 50 to 100 percent rod density, a pattern which can only be monitored by the RWM, not the RSCS. Thus the RWM can currently be considered an acceptable system for rod pattern control.

The proposal for GESTAR II changes and TS change examples for reactors electing to remove the RSCS do not propose any minimal RWM use or restrictions on the substitution of second operators for the RWM. The staff review of this proposal and the past effectiveness of restrictions on RWM bypass has concluded that the TS accompanying a removal of the RSCS should provide for minimizing operation without the active use of the RWM. 9/88

The specifications should provide strong incentives for RWM maintenance and use without engendering excessive operational restrictions. Furthermore, the review concludes that the occasional necessary use of a second operator RWM replacement should be strengthened by a utility review of relevant procedures, related forms and quality control to assure that the second operator provides an effective and truly independent monitoring process. A discussion of this review should accompany the request for RSCS removal.

3.4 RSCS Requirements

It can be concluded from the above discussion that the "perceived" problems listed at the beginning of Section 3.0 have been satisfactorily addressed since the RSCS was required on new reactors. The probability study, improved calculations and RWM acceptability have alleviated the concerns expressed at that time. The changes in the three listed areas may be briefly summarized as follows.

1. Improved methodology studies (and to a lesser extent improved rod patterns) indicate that a RDA involving no errors in the rod pattern would result in peak enthalpy far below NRC limits, and even with maximum single error (and most multiple error) patterns would not exceed limits. Furthermore the probability level of exceeding enthalpy limits is very low even without consideration of these greater margins.

2. RWM TS improvements have improved RWM reliability and use, and computer controlled systems are considered acceptable.

3. Probability and methods studies have advanced sufficiently to modify initial perceptions.

The review thus concludes that the RSCS is not needed and operation without it is acceptable. However, the review also concludes, as previously indicated, that suitable provisions should be made for RWM use and operator backup, and rod patterns should be in accord with BPWS concepts.

The proposal indicates that in addition to the lack of need for the RSCS there is further incentive for its removal based on the added system and operation complexity and time consumption produced by the RSCS. This is particularly true for the GNRSCS [illegible]tors for which many hours of tedious operator actions are added to low po[illegible] operations. The review concludes that these are appropriate incentiv[illegible] or RSCS removal, given the conclusion that operation is acceptable without the RSCS.

3.5 RWM Cutoff Power Level

In addition to the removal of the RSCS the proposal requests a lowering of the cutoff power level for required RWM (and RSCS where still applicable) operatic from 20 to 10 percent power. This is based on existing calculations which demonstrate that no significant RDA can occur above 10 percent power. This is acceptable since both the old GE calculations and, as previously discussed, th

BNL calculations indicate that by 10 percent power peak fuel enthalpy is reduced well below required limits, even for significant error patterns. This is because of the reduced available rod worth and more effective action of feedback mechanism (even when assuming no direct moderator heating). The 20 percent limit was required as an extreme bound because of then existing uncertainties in the analysis. Based on current analyses the 10 percent level is acceptable.

3.6 TS and GESTAR II Changes

The removal of the RSCS and lowering of the RWM turnoff setpoint requires some TS changes. These would vary in detail for various reactors depending on existing TS format. The proposal presents sample TS changes which could be followed or used as a model. These examples deal with only RSCS removal (removing references to the RSCS) and lowering of the setpoint. These are satisfactory models for that purpose, but are not sufficient. As previously discussed, the staff review has concluded that RWM TS should require provisions for minimizing operations without RWM use as was previously done for operating reactors. Thus a RSCS removal request should include such TS changes. In addition, as also discussed, the request should present a discussion of the review of second operator procedures. Finally it is recommended that a BPWS pattern or its equivalent (or an improved version such as the Reduced Notch Worth Procedure) be used in order to reduce potential maximum rod worths. 9/88

The submittal included proposed changes to GESTAR II (as Amendment 17 to NEDE-24011-P) necessary to recognize the removal of the RSCS and the change in the setpoint in that document. These are straight forward, editorial type changes and are acceptable. However, there should also be in GESTAR II some direct statement, beyond the proposed references to the BWROG letter and associated report (Reference 1), of the above requirements for TS change and second operator procedures review.

4.0 CONCLUSIONS

At the time the RSCS and 20 percent power rod pattern control cutoff were required for new reactors for RDA mitigation there were numerous perceived problems associated with the RDA. In the intervening time these problems have been resolved and the need for the RSCS (and the RWM above 10 percent power) is no longer apparent. The probability study, independent improved RDA calculation results, BPWS rod patterns, and improved RWM operability have contributed to this resolution. Furthermore, there is sufficient incentive in the reduction of unneeded operational complexity and in some cases wasted low power operating time and emergency power reduction to justify removal of the system. The review has thus concluded that it is acceptable to remove the TS requirements for the RSCS for those BWR 4 and 5 reactors which have either the GN or BPWS RSCS, and to lower the turnoff setpoint for the (required) RWM to 10 percent power. 9/88

The proposed Amendment 17 changes to GESTAR II indicating these changes are acceptable as are the proposed example TS changes. However, it is required that the TS for the RWM for these reactors be altered to require use of the RWM to an extent which would minimize substitution of a second operator and thus provide a strong incentive to maintain and improve that system. It is also required that utilities requesting RSCS removal review the procedures, independence and quality control for second operator substitution and provide a discussion of that review. Finally, it is recommended that rod patterns used for these reactors be at least equivalent to BPWS patterns. These requirements should be directly stated in GESTAR II.

5.0 REFERENCES

1. Letter from T. A. Pickens, BWROG, to G. C. Lainas, NRC, dated August 15, 1986, "Amendment 17 to General Electric Licensing Topical Report NEDE-24011-P-A."

2. Letter and enclosure from B. C. Rusche, NRR, to R. Fraley, ACRS, dated June 1, 1976, "Generic Item IIA-2 Control Rod Drop Accident (BWRs)."

3. BNL-NUREG 28109, "Thermal-Hydraulic Effects on Center Rod Drop Accidents in a Boiling Water Reactor", H. Cheng and D. Diamond, October 1980.

4. NEDO-2131, "Banked Position Withdrawal Sequence", C. Paone, January 1977.

5. Memorandum from V. Stello, NRR, to K. Goller, NRR dated July 21, 1975, "DTR Determination on the Need to Backfit Certain BWRs with Additional RDA Protection."

6. Letter and attachment from C. Thomas, NRC, to J. Charnley, GE, dated October 11, 1985, "... NEDE-24011 ... Revision 6, Amendment 12."

7. Letter to J. Hendrie from M. Bender, "Status of Generic Items Relating to Light-Water Reactors: Report No. 6", November 15, 1977.