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EFFECT OF RECIRCULATION PUMP TRIP FOLLOWING ANTICIPATED TRANSIENTS WITHOUT SCRAM AT BIG ROCK POINT

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INTERIM REPORT

EFFECT OF RECIRCULATION PUMP TRIP FOLLOWING ANTICIPATED TRANSIENTS WITHOUT SCRAM AT BIG ROCK POINT

June 1982

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ABSTRACT

As a part of the Big Rock Point Probabilistic Risk Assessment, Consumers Power Company has submitted analyses regarding the effect of recirculation pump trip following an anticipated transient without scram. This report provides a discussion of those analyses and the results derived from them.

FOREWORD

This report is supplied as part of the "Review of Risk Study at Big Rock Point" being conducted for the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Division of Safety Technology, by EG&G Idaho, Inc., Reliability and Statistics Branch.

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EFFECT OF RECIRCULATION PUMP TRIP FOLLOWING ANTICIPATED TRANSIENTS WITHOUT SCRAM AT BIG ROCK POINT

1. INTRODUCTION

As requested by the U.S. Atomic Energy Commission (now U.S. Nuclear Regulatory Commission) in their Technical Report on Anticipated Transients Without Scram (ATWS) for Water-Cooled Reactors (WASH-1270), Consumers Power Company (CPC) has submitted analyses which describe the response of their Big Rock Point (BRP) Plant to an ATWS. The original analyses were submitted on November 21, 1975,[1] and the results indicated that a recirculation pump trip (RPT) was very effective in limiting the consequences of an ATWS. The response of BRP to an ATWS was reanalyzed as a part of the Big Rock Point Probabilistic Risk Assessment (PRA). Results of the analysis were submitted on February 26, 1981,[2] with the conclusion that automatic RPT provides little safety improvement at BRP. This conclusion was based on an overall assessment of risk contributors at BRP. The purpose of this report is to evaluate the recirculation pump trip analysis results which were input to the PRA, as documented in Reference 2. Additional information was submitted by CPC on September 10, 1981,[3] and December 17, 1981,[4] in response to questions resulting from the preliminary review.

2. TECHNICAL DISCUSSION

2.1 Transient Description

Regulatory Guide 1.70 specifies seven transients which are to be considered as initiators for an ATWS. For the purpose of the analysis, it is assumed that the reactor is operating at rated power when the transient occurs. The transient generates a reactor protection system trip signal; however, the control rods fail to insert.

Following detection of the failure to scram, the operator will attempt a manual scram followed by a trip of one or more recirculation pumps. Other methods of achieving shutdown will be attempted, culminating in actuation of the liquid poison system. The basic premise throughout the analysis for Big Rock Point is that shutdown must be achieved prior to actuation of the Reactor Depressurization System (RDS). Failure to do so is postulated to result in probable core damage as well as possible containment damage.

Specific response of the reactor to an ATWS depends on the initiating event and the availability of supporting systems such as the main condenser and the feedwater system. The Big Rock Point analysis groups the transients into four categories:

1) Infinite Feedwater Transients

2) Low Level Transients

3) High Pressure Transients with Limited Feedwater

4) High Pressure Transients with No Feedwater.

The first category, infinite feedwater, assumes that the feedwater system and main condenser remain operational. The reactor continues to produce power which is dissipated in the condenser until shutdown is achieved. An infinite feedwater transient will only lead to core damage if it degrades into one of the other categories or if long-term cooling fails after shutdown of the reactor. Thus this category of transient has not been analyzed in detail.

The low level transient which has been analyzed is a loss of feedwater. The turbine control system is assumed to operate normally to maintain normal system pressure until the turbine trips on low steam drum level, following which the dump valve opens and continues to deplete reactor inventory until the reactor is shutdown or RDS actuation occurs.

The high pressure transient with limited feedwater which has been analyzed is a turbine trip without bypass. Feedwater is assumed to be available until the hotwell level drops to the point where the condensate pump trips after which the transient is similar to the loss of feedwater transient, except that system pressure is maintained by the safety valves rather than the steam dump system.

The high pressure transient without feedwater which has been considered is the loss of station power. This transient has not been specifically analyzed but has been shown to be limited by the two analyzed cases, and simplified calculations have been made to determine required operator response times.

The analyses presented initially by CPC bounded all initiators identified by Regulatory Guide 1.70 except for the inadvertent control rod withdrawal. CPC stated that it was not considered, as the probability of this initiator was felt to be much less than other initiators, thus the risk contribution would be less. As a result of further questioning, CPC provided data for a rod withdrawal initiated ATWS.

2.2 Analysis Results

Reactor response to an ATWS is calculated using a RETRAN[5] model of the BRP primary coolant system. Although CPC has submitted information which tends to validate the use of RETRAN for BRP analysis, the RETRAN code has not received full NRC review. As it becomes available, additional information, possibly including data from the FIST facility will be reviewed for applicability to this study, and any impact on the conclusions herein will be assessed.

Containment pressure response is calculated based on an approximation derived from earlier calculations and is given by the equation

$$P = (3.6 \times 10^{-4})\, M_{steam}$$

where P is the containment pressure (psig) and M_{steam} is the mass of steam dumped to the containment during blowdown.

A comparison of this approximation with Figure VII.1 of Reference 6 indicates that the approximation is probably valid for the area of interest here. It should be noted that the actual response as shown on the figure is nonlinear at higher steam inputs and the equation will tend to underpredict the pressure. Thus the approximation should not be used in the event that the analysis is ever extended to higher steam inputs.

The results of the analysis show that, if reactor shutdown can be achieved prior to RDS actuation, the consequences of the transient are acceptable. The reactor power stabilizes at an acceptable level with energy being removed by the condenser, if available, or the safety valves. Sizing of the safety valves is adequate to prevent system overpressurization. Based on a limited amount of feedwater, containment pressure will be maintained below design pressure.

In the event that RDS actuation occurs prior to shutdown, core damage is predicted to occur. The BRP PRA also predicts that containment overpressurization failure could occur between 16 and 49 minutes after RDS, but further says that the understanding of the processes by which liquid poison mixes in the core following RDS actuation is inadequate to predict nuclear shutdown prior to 50 minutes after RDS actuation. Therefore, failure to achieve shutdown prior to RDS actuation is predicted to cause containment failure.

Two areas of potential non-conservatism in the analyses were identified during the preliminary review. CPC subsequently provided clarification of these areas and their effect on the analysis results.

The first area dealt with the use of nominal values for the initial volumes for the steam drum and hotwell. CPC has provided information which identifies the expected variations to be ±900 lbm for the steam drum and ±2500 lbm for the hotwell. If the volumes were low by that amount, operator response times would be reduced by from 3 to 15 seconds, depending on the sequence. Specific variations are identified in Table 1. If the volumes were higher than nominal, more mass is available to dump to the containment prior to RDS actuation, resulting in a higher containment pressure. This is discussed in more detail below.

The second area concerned a potential delay in operator response until the ATWS was identified. This is particularly significant for the low level transient. CPC has confirmed that normal reactor trip is not expected until approximately 25 to 35 seconds into the transient. Thus the operator would not be aware of a problem and would not be expected to initiate any action until after this delay. For high pressure transients, this factor is not significant, as normal reactor trip is expected within a few seconds of transient initiation.

The main parameter of concern in these analyses is the required operator response time. The available response times for various sequences are shown in Table 1. All times given in the table are with reference to the start of the initiating transient. As noted in the above paragraph, the actual failure to scram may not occur until some time into the transient. The limiting sequence for a transient initiated by either a rod withdrawal or a loss of feedwater is the low level sequence. For the loss of feedwater the time from transient initiation to RDS actuation is 145 seconds, without RPT. Subtracting the mixing time for LPS, the operator alert time, and the uncertaintity in initial volumes, the operator has 64 seconds to initiate LPS. If he actuates RPT in this time frame he has up to an additional 2 minutes to actuate LPS. For the rod withdrawal initiated ATWS, the operator action time without RPT is reduced to 39 seconds. Early recirculation pump trip will again increase this time by about 1-1/2 to 2 minutes.

The limiting sequence for containment pressure is a high pressure with limited feedwater transient. This sequence provides for maximum steam dump to containment without RDS actuation, and results in a maximum containment pressure of 22 psig using nominal initial volumes. With the uncertainties in initial volumes at the maximum, the peak pressure will be 23 psig. Both of these values are below the design pressure of 27 psig.

2.3 Comparison With Previous Analyses

A comparison of the results of this analysis with those obtained in NEDE-21065 shows a significant difference, particularly in the area of maximum containment pressure. The main reason for the difference lies in the assumption of the availability of feedwater for the duration of the transient in NEDE-21065. The additional mass input into the containment results in significantly increased containment pressures. In the current analysis the feedwater is limited and the critical factor becomes the time before the level drops to the point at which RDS is actuated. In the original analysis, which was time limited, the reduced power caused by RPT resulted in a significant reduction in containment pressure whereas in the current analysis, which is mass limited, all available mass is assumed dumped to the containment whether or not RPT occurs, resulting in the same pressure. RPT just delays the time for which operator action must be taken to prevent RDS actuation.

A comparison of the current analysis of a turbine trip with a previous analysis having approximately the same LPS initiation time, both with and without recirculation pump trip, was made. For the case without RPT, the original analysis resulted in a significantly higher peak pressure (42.3 psig vs. 22 psig). There are several factors which contribute to this difference. Both analyses show a short transient peak in reactor power, followed by a steady state power level. In the original analysis, steady state power following the peak is projected to be about 110% and to remain there until LPS begins to take effect. A time of 300 seconds is assumed from this point until shutdown is achieved. The current analysis assumes a steady state power of approximately 90% until feedwater is lost at which time the power drops to 50% and remains there until the LPS takes effect. From this point on a time of 11 seconds is assumed until shutdown is achieved. This combination of lower power levels and faster shutdown both contribute to a lower steam release and subsequent containment pressure. CPC was requested to provide a clarification of the difference in steady state power level early in the transient (110% for the original anaysis vs. 80% for the current analysis). Information submitted in response to that request identified several items which contribute to this difference. The original analysis was performed assuming worst case core conditions, whereas the current RETRAN analysis is intended to be a best estimate analysis of plant response. Additionally, although it is not apparent from the analyses presentations, CPC has stated that the original analysis assumed a reactor operating pressure of 1500 psia and a safety valve setpoint of 1750 psia, compared to current values of 1350 psia for the operating pressure and a range from 1550-1600 for the safety valve setpoints.

3. SUMMARY AND CONCLUSIONS

The analyses presented by CPC indicate that the BRP plant can recover safely from an ATWS event, however, with the present design, operator action is required in a very short time frame. Current analysis assumes that if reactor shutdown cannot be achieved prior to RDS actuation, core damage and containment failure are likely to occur. In order to prevent RDS actuation during the limiting transient, operator action is required in less than one minute to initiate RPT or LPS. If RPT is accomplished in this time frame, then the operator has up to two minutes additional in which to achieve reactor shutdown. The limiting transient addressed here is the low level transient initiated by an inadvertent control rod withdrawal. CPC has stated that this initiator is a lower probability event and thus not a significant contributor to ATWS. However, even the higher probability initiators give a limiting operator response time of just over one minute.

Recirculation pump trip, either automatic or manual, is effective in delaying the time at which the operator is required to take action to initiate LPS injection following an ATWS. Assuming that reactor shutdown can be achieved prior to RDS actuation, RPT has no direct effect on the consequences of the transient. The maximum available mass that can be dumped to the containment without RDS actuation is limited such that the containment design pressure will not be exceeded. However, it has been noted that the LPS is not environmentally qualified, hence any steam release to the containment will tend to degrade the system. Early RPT will tend to minimize the amount of steam released until the operator can initiate LPS, thus increasing the probability that the system will operate correctly when it is actuated.

Current NRC licensing practice has generally approved time periods of not less than 10 minutes for operator actions. The time available for the BRP operators to respond to an ATWS are significantly less than this. NRC has been allowing shorter response times where the actions required are shown to be very simple and where there is good indication that action is needed. CPC has prepared an Emergency Procedure (EMP 3.5A) which describes the expected operator response to an ATWS. Based on this procedure, there is no direct annunciation of an ATWS condition. The operator must detect the ATWS by observation of parameters that indicate the requirement for a scram, i.e., reactor scram inputs, coupled with observation of other parameters which indicate that a scram has not occurred, i.e., control rod position, flux level and system pressure. He then has a series of actions which he is instructed to take prior to actuation of the LPS. Based on the available indications and the number of required actions, it appears that the BRP procedure does not meet current NRC licensing criteria. Consumers Power Company has attempted to justify their current design by means of probabilistic risk assessment techniques. This approach is the subject of another study and is beyond the scope of this review.

4. REFERENCES

1. P. M. Gururaj, "Anticipated Transients Without Scram Study for Big Rock Point Power Plant," NEDE-21065, October 1975.

2. Letter, G. C. Withrow, Consumer Power Company to Director, Nuclear Reactor Regulation, February 26, 1981.

3. Letter, T. C. Bordine, Consumers Power Company, to Director, Nuclear Reactor Regulation, September 10, 1981.

4. Letter, T. C. Bordine, Consumers Power Company, to Director, Nuclear Reactor Regulation, December 17, 1981.

5. "RETRAN--A Program for One-Dimensional Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems," EPRI CM-5, December 1978.

6. Consumers Power Company, Probabilistic Risk Assessment, Big Rock Point Plant, March 31, 1981.

TABLE 1. OPERATOR RESPONSE TIME FOR ATWS EVENTS[a]

Transient	Time to RDS Seconds		Time to Mix LPS Seconds		Operator Alert Time Seconds		Operator Time to Inject Poison, Seconds[b]	
	A	B	A	B	A	B	A	B
Low Level								
(Loss of Feedwater)								
No RPT	145	108	41	41	35	25	69(±5)	42(±3)
RPT @ 80 seconds	268	---	75	--	35	--	158(±8)	---
RPT @ 60 seconds	287	188	75	62	35	25	177(±8)	101(±6)
RPT @ 35 seconds	312	213	75	62	35	25	202(±8)	126(±6)
High Pressure with Feedwater								
(Turbine Trip w/o Bypass)								
No RPT	267	181	41	41	--	--	226(±15)	140(±8)
RPT @ 60 seconds	430	294	75	62	--	--	355(±15)	232(±14)
RPT @ 8 seconds	530	330	75	62	--	--	455(±15)	268(±14)
High Pressure No Feedwater								
(Loss of Station Power)								
RPT @ 60 seconds	309	209	75	62	--	--	234(±8)	147(±6)
RPT @ 0 seconds	350	250	75	62	--	--	275(±8)	188(±6)

a. "A" column is initiation by other than inadvertent rod withdrawal "B" column is with rod withdrawal initiation.

b. Includes uncertainty due to other than nominal steam drum and hotwell volumes.