ATTACHMENT 1

PROBABILISTIC RISK ASSESSMENT

OF

AUTOMATIC RECIRCULATION PUMP TRIP

BIG ROCK POINT PLANT

December 1980

nu1280-0037b-43

8012080365

INTRODUCTION

ATWS sequences are to be examined as a part of the Big Rock Point Risk Assessment. The transients which contribute to ATWS and their frequencies will be a compilation of EPRI generic data, General Electric generic information and actual Big Rock Point Plant experience. This probability of failure to SCRAM has generally been conceded to be a result of common mode failure and, therefore, difficult to qualify for any particular plant. As a result, SCRAM failure probability will be based on the legislated frequency of WASH-1270. With this as a basis, ATWS sequences are believed to be as significant a contributor to the probability of core damage as other accident or transient sequences.

Mitigation of the consequences of BWR ATWS sequences has most recently fallen on automatic recirculation pump trip (RPT). This feature has been examined using the Probabilistic Risk Assessment (PRA) made in the stage to which it has developed to determine its detrimental or beneficial effects.

The conclusions reached at this time are: There is no detrimental effect on core damage probability or risk resulting from automatic RPT, there is no significant beneficial effect resulting from its installation and there are other plant modifications which do have a significant beneficial effect on core damage probability whether or not the automatic RPTs' trip feature is installed. The basis for these conclusions is summarized below and results from basic design differences between Big Rock Point and current product line BWRs.

The summary begins with a brief description of the Big Rock Point primary coolant and liquid poison systems. A listing of the transients for which RPT may be important follows. Preliminary core damage probability figures from the risk assessment model concludes the summary. It should be kept in mind throughout that the only manual action assumed in this study is that which is necessary to inject liquid poison. No credit has been taken for manual action to trip the recirculation pumps.

SYSTEM DESCRIPTION

Attachment A is a simple line diagram (Figure 1) of the primary coolant system for the Big Rock Point Plant. Six (14-inch) risers connect the reactor vessel to the steam drum. Four (17-inch) downcommers external to the vessel provide suction to the two centrifugal recirculation pumps. Each pump discharges to a 20-inch nozzle in the bottom of the vessel. Total recirculation flow with both loops in service is approximately 1.2×10^6 lb/h. Tripping one recirculation pump from near rated conditions results in a final steady state power reduction to 60% original power. An additional 10% reduction in power is obtained by tripping the remaining pump.

Unlike most BWRs, six spring loaded relief valves on top of the steam drum provide relief capability up to 138% rated power. Set at 10 psig increments beginning at 1535 psig, this relief capability prevents primary coolant pressure from exceeding system design of 1700 psig, even during an ATWS event (see FHSR Section 12, Pages 11, 28 and 41). Normal operating pressure is 1335 psig.

For small and intermediate Loss of Coolant Accidents, a reactor depressurization system (RDS) is provided. Coincident signals resulting from low steam drum level (and a two-minute time delay) and low reactor water level will result in a blowdown of the primary system through the steam drum to containment. This blowdown from rated conditions results in core uncovery. Low-pressure core sprays then provide water makeup necessary to cool the core. Unlike more recent BWR designs, Big Rock has no high-pressure injection system other than feedwater and control rod drive systems.

Also, unlike current product line BWR plants, the liquid poison system at Big Rock does not require a positive displacement pump for poison injection. A bank of nitrogen bottles provides the force necessary to begin poison injection once the squib valves have been actuated from the control room. Sufficient nitrogen pressure exists to establish a siphon from the 850-gallon liquid poison tank to the primary system even with reactor pressure at the highest relief valve set point. A vent from the steam drum to the poison tank exists to insure siphoning action continues once established.

Sufficient poison can be siphoned to the core to result in shutdown within five minutes. Flow of poison to the core can occur through two paths, one to the suction of the recirculation pumps, the other directly into the vessel in the vicinity of the recirculation loop inlet nozzles. Control of poison flow to the suction of the pumps is provided by CV 4050. This path is available only when one or both pumps are running. Under this condition, it is believed a siphon can be established by the pump suction pressure even without the benefit of nitrogen pressure.

TRANSIENTS AFFECTED BY RPT

The second attachment (Figure 2) contains a list of transients which would result in automatic trip of the recirculation pumps either by low drum level or high primary system pressure. The frequency of occurrence per year for each of these transients is indicated in brackets.

The dynamics of the secondary side of the plant are such that feedwater is lost any time a demand on the turbine bypass valve occurs near full power. Hence, the majority of transients which are potentially affected by RPT result in near immediate loss of feedwater and fall in the low drum level transient category. The remaining transients are evenly split between high-pressure/no feedwater events (such as loss of off-site power) and high-pressure/limited feedwater events (main condenser and bypass failure events in which feedwater does not trip until the hot well is dry - 3000 gal).

On categorization of these transients, the effect of RPT on failure to SCRAM from full power can be determined. As discussed previously, RPT is of no benefit in preventing reactor overpressurization due to the large relief capacity at Big Rock. Some benefit can be obtained in mitigating containment overpressurization, however. Additional time to initiate manually the liquid poison system is possible also.

Manual initiation of the poison system is required to prevent either of two occurrences which may result during Big Rock ATWS events, RDS actuation and recriticality on reflood due to core spray. Prevention of RDS during ATWS is important for two reasons. First, long-term cooling systems within containment normally used for shutdown of the Plant may be of no use once RDS actuation occurs. The number of systems available to keep the reactor in shutdown will be limited to emergency core cooling systems. Second, if water inventory in the primary system drops below the core, as it would during RDS, the mechanism for mixing the poison once injected becomes unclear. Recriticality may occur to some extent whether or not poison has been injected to the vessel until thorough poison mixing is eventually achieved.

Returning to Figure 2, the time required to initiate poison injections to prevent each of these events after an ATWS from full power is presented. Note that it is assumed RDS actuation cannot be prevented for any transient in which feedwater is lost early in the event. For these events, whether initiated by high pressure or low level, RDS actuation occurs within several minutes, an insufficient period of time to initiate, inject and mix the poison. RDS can be prevented by tripping the recirculation pump quickly during those transients which do not result in loss of feedwater until the hot well is empty.

Assuming some mixing mechanism is available, sufficient time does exist to prevent recriticality on reflood for all transients. Note, however, during transients in which the pumps are tripped on low drum level, only an additional 11 seconds are available to begin poison injection. A more significant increase in time for poison injection occurs for high-pressure transients without feedwater, but note that each of these transients are those which would result in RPT on loss of potential anyway. Automatic RPT is of little benefit; therefore, in limiting core damage during the majority of transients which are expected to occur at Big Rock, only those high-pressure events which do not result in loss of feedwater early in the event derive any benefit from tripping the recirculation pumps (less than 20% of ATWS transients under consideration for this study).

Similar arguments apply to the effect of RPT on limiting containment damage during ATWS. Low-level transients do not result in a demand on containment as the main condenser continues to serve as the heat sink through most of the event. As before, high-pressure/no feedwater events result in RPT but on loss of potential without an additional automatic feature. Once again, the only transients which appear to benefit at all from the automatic RPT are the approximately .2 high-pressure events per year which do not result in immediate loss of feedwater.

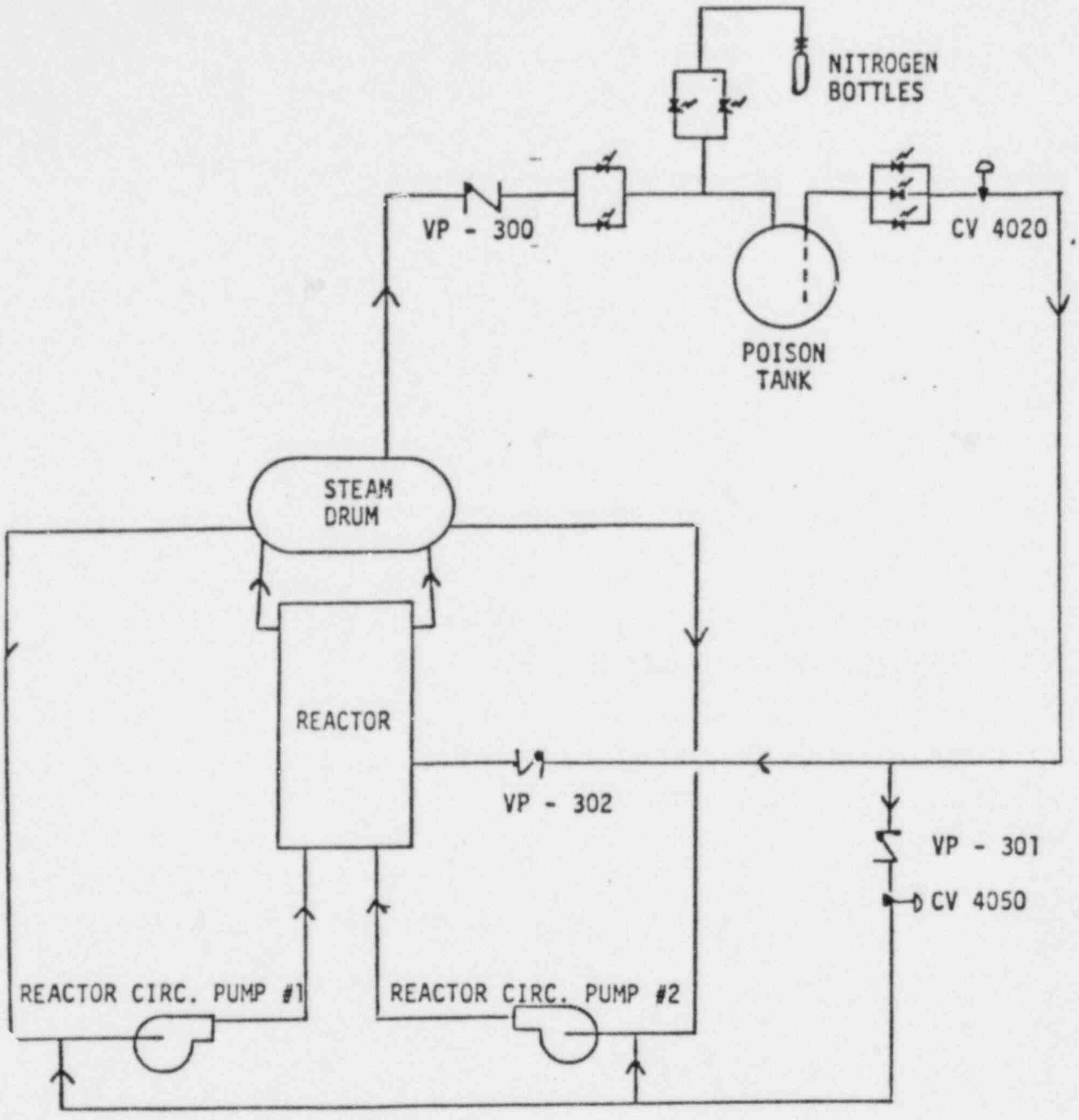
RISK ASSESSMENT RESULTS

It will be recalled from the liquid poison system description that two paths exist by which poison can reach the vessel. It can be argued that tripping the recirculation pumps and thus closing CV 4050 eliminates the path to the pump suction and prevents the benefit of mixing the poison with primary coolant through the pumps. No argument to this effect will be made. It is believed, due to the flow conditions which exist in the lower plenum of the vessel and the proximity of the poison nozzle to the recirculation loop nozzles, that adequate mixing of poison with coolant exists using either path. In addition, the liquid poison system fault tree indicates the detrimental effect of eliminating the path to the recirculation pump suction is not significant, especially when compared to the failure probability of manual action to initiate poison injection.

In some cases, fault tree analysis indicates a detrimental effect of using the path to the suction of the recirculation pumps to inject poison. For those transients in which primary coolant inventory is very low, circulation through the recirculation loops will not be occurring. Under this condition, instances in which the recirculation pumps are not tripped or CV 4050 fails open can result in diversion of poison to the stagnant loops rather than the vessel. Fault tree analysis indicates a control system for CV 4050 other than the recirculation pump breakers may be beneficial. This is the only benefit which may be considered significant, provided by tripping the recirculation pumps.

As for the effect of RPT on allowing more time to inject liquid poison, recall that only those transients which do not result in immediate trip of the feed pumps derive any benefit. Risk assessment results of the benefits of RPT are shown on Figure 3. Only a small reduction in core damage probability occurs by installing automatic RPT over not tripping the pumps at all. Other potential modifications are presented as well. Automatic liquid poison appears to have similar limited effect. Increasing the inventory available to inject as feedwater appears to have the most beneficial effect reducing core damage probability by a factor of three.

The risk assessment at this time, therefore, indicates if anything is to be done to reduce the probability of core damage at Big Rock due to ATWS, efforts should be directed more toward increasing feedwater inventory and reliability than by reducing power by automatically tripping the recirculation pumps. Due to the inherent differences between Big Rock and more recent BWR designs, this effort would be theoretically directed at preventing RDS during ATWS events and could have a beneficial effect on more core damage sequences than the currently proposed automatic RPT.



LIQUID POISON SYSTEM

FLOW DIAGRAM

FIGURE 2

TIME FOLLOWING VARIOUS TRANSIENTS AVAILABLE TO BEGIN LPS INJECTION (SEC)

INITIAL/FINAL POWER (MWT)	LOW LEVEL TRANSIENT [1.0]	HI PRESSURE NO FW [0.2]	HI PRESSURE FW FROM HOTWELL [0.2]
	<u>PREVENT</u> RDS RECRIT	<u>PREVENT</u> RDS RECRIT	<u>PREVENT</u> RDS RECRIT
240/120 AUTO RCPT	- 155	- 218	164 464
NO RCPT	- 144	- 144	- 267
TRANSIENTS*	[.40] TURBINE TRIP [.10] IPR FAILURE [.06] BYPASS OPEN [.06] LOSS FW [.40] LOAD REJECT (ALL WITH BYPASS)	[.01] LOSP [.004] LOAD REJECT (NO BYPASS) .10 LOSP .10 LOSS AUX. POWER (WITH BYPASS)	[.04] TURBINE TRIP [.01] IPR FAILURE (NO BYPASS) [.06] MAIN COND. FAIL [.06] MSIV CLOSURE [.04] LOAD REJECT (FW MANUAL RESTART)

*NUMBERS IN BRACKETS INDICATE FREQUENCY OF OCCURRENCE OF THAT PARTICULAR TRANSIENT PER YEAR

EFFECTIVENESS OF PROPOSED MODIFICATIONS ON ATWS CORE DAMAGE PROBABILITY

AS IS	AUTO RCPT	AUTO SLC	LIMITED FW	
5.0×10^{-5}	4.7×10^{-5}	4.7×10^{-5}	1.6×10^{-5}	
		4.7×10^{-5}	1.1×10^{-5}	AUTO RCPT
			1.3×10^{-5}	AUTO SLC
			1.1×10^{-5}	FW (LIMITED) AUTO SLC & AUTO RCPT

FIGURE 3