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EFFECT OF REACTOR CONDITIONS ON MSIV-ATWS POWER LEVEL*

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In a boiling water reactor (BWR) when there is closure of the main steam isolation valves (MSIVs), the energy generated in the core will be transferred to the pressure suppression pool (PSP) via steam that flows out of the relief valves. The pool has limited capacity as a heat sink and hence, if there is no reactor trip (an ATWS event), there is the possibility that the pool temperature may rise beyond acceptable limits.

There are automatic safety features and operator-initiated emergency procedures whose objective is to reduce core power until the time when the standby liquid control system, or other attempts to get control rods inserted, can effect shutdown of the core power. One emergency procedure for a BWR/4 would require the operator to reduce the flow of high pressure coolant injection into the reactor. The core inlet flow rate at this time would be due to natural circulation and the reduced flow would lower the water level in the downcomer, thereby reducing the natural circulation flow rate. This effect, and the reduction in core inlet subcooling due to mixing of this emergency feedwater with steam in the downcomer when the level was lowered, cause a sufficient increase in core void fraction so that the power would be reduced.

A reduction in pressure might also be called for during this event in order to comply with the PSP heat capacity temperature limit or to prevent cycling of relief valves.

The present study[1] was undertaken to determine how the initial reactor conditions affect the power level during an MSIV-ATWS event. The time of interest is during the 20-30 minute period when it is assumed that the reactor is in a quasi-equilibrium condition with the water level and pressure fixed, natural circulation conditions and no control rod movement or significant boron in the core. The initial conditions of interest are the time during the cycle and the operating state.

Table I summarizes the results of considering the effect of the fuel cycle on the MSIV-ATWS power level. It indicates the time during the cycle when the power level would be highest (i.e., the worst time), as the result of a particular parameter. The parameters are affected by the time during the cycle because of the burnup of fuel and poisons, the buildup of fission products and actinides, the change in control rod density, and in the case of the Doppler effect, the change in gap conductance.

The table shows that the effect of void feedback alone is likely to be worst at either beginning-of-cycle (BOC) or end-of-cycle (EOC); whereas, the effect of Doppler feedback would make either BOC or middle-of-cycle (MOC) the worst time. These results were based on reactivity coefficients calculated with a core simulator for data from 4 cycles of one reactor[2] and one cycle of another.[3] The combined effect of void and Doppler would be worst either at BOC or EOC with 3 out of 5 cases BOC.

The effect of moderator temperature feedback is worst at MOC. However, this is only relevant for those cases where there is a depressurization. The effect of decay heat makes EOC worst with the resultant power approximately 2% of rated power higher relative to BOC. The effect of the time during the cycle on delayed neutron fraction is not important as the power level is not affected by the delayed neutron fraction.

As a result of all these different effects it is not possible to know a priori the net effect, i.e., to predict where in the cycle the quasi-equilibrium power will be highest. This can only be done with detailed calculations under ATWS conditions at various points during the cycle.

The effect of operating conditions on the quasi-equilibrium power level during an MSIV-ATWS is summarized in Table II. The entries show the ATWS power level with different initial conditions relative to the power level expected when the initial conditions are full power and flow with equilibrium xenon. The only conditions that lead to higher powers than expected for the base case are the situations with reduced xenon level compensated for with reduced flow and operation in the extended load line region. For these cases the change in power level was quantified using the BNL Plant Analyzer.[4] It was found that for approximately every $1 in reactivity compensated for with reduced flow, the final ATWS power would be 2% of rated power higher.

In the past, studies of the power level under the MSIV-ATWS conditions described herein have usually assumed EOC and full power and flow as the reactor conditions. The present study determines whether other conditions would be more limiting. In particular, the effect of time during the cycle and initial operating conditions have been studied systematically.

REFERENCES

1. D. J. Diamond, "Effect of Initial Conditions on MSIV-ATWS Analysis," BNL Technical Report, Brookhaven National Laboratory (1987).

2. D. C. Albright, et al., "Vermont Yankee Cycle 11 Core Performance Analysis," YAEC-1403, Yankee Atomic Electric Co. (1984).

3. R. V. Furia, personal communication, GPU Nuclear (1986).

4. W. Wulff, et al., "The BWR Plant Analyzer," NUREG/CR-3943, Brookhaven National Laboratory (1984).

TABLE I

Time (X) During Cycle for Highest MSIV-ATWS Power Based on Various Parameters

	BOC	MOC	EOC
Void Feedback	X	-	X
Doppler Feedback	X	X	-
Combined Void & Doppler	X	-	X
Temperature Feedback	-	X	-
Decay Heat	-	-	X
Delayed Neutron Fraction	-	-	-

TABLE II

Effect of Operating Condition on MSIV-ATWS Power

Change in Operating Condition	Power Relative to Nominal Case: Increase	Same	Decrease
Non-Equilibrium Xenon			
Reduced Flow	X	-	-
Control Rod Insertion	-	X	-
Reduced Flow			
ELLR[a]	X	-	-
Increased Flow			
ICFR[b]	-	-	X
PFH[c]	-	-	X
Reduced Power			
Reduced Flow	-	X	-
Control Rod Insertion	-	-	X

Notes

a. Extended load line region
b. Increased core flow region
c. Partial feedwater heating