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STEAMLINE BREAK OUTSIDE CONTAINMENT MASS ENERGY RELEASE ANALYSIS TVA - WATTS BAR

MARCH 29, 1985

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INTRODUCTION

Mass/energy releases following a steamline rupture are used to determine the temperature profiles for qualification of equipment. The temperature profile is a function of both the steam blowdown and the compartment in which the equipment is located. This analysis provides information for use in evaluating the effects of steam generator tube bundle uncovery and the associated superheated steam generation for areas outside containment.

This analysis identifies the relationship between the time of safety actuations and the time of tube bundle uncovery in order to determine where safety function actuations may be challenged due to the superheated steam generation. The safety functions which may be required in the event of a steamline rupture and which were addressed in this analysis are: reactor trip, safety injection, steamline isolation, feedline isolation, auxiliary feedwater flow initiation and auxiliary feedwater flow realignment. The time of tube bundle uncovery depends upon several factors including initial conditions, break size, and the main and auxiliary feedwater flowrates. This analysis utilized limiting assumptions to predict the earliest tube bundle uncovery and to determine the areas of concern where required safety actuations may not occur prior to steam generator tube bundle uncovery. These areas are defined as a function of break size and initial power level. Mass and energy releases are provided for the limiting break sizes and power levels where tube bundle uncovery preceeds a safety actuation.

ANALYSIS DESCRIPTION

The LOFTRAN code was used in this analysis and is a digital computer code developed to simulate the transient behavior of a multi-loop pressurized water reactor system. LOFTRAN simulates neutrom kinetics, thermal-hydraulic conditions, pressurizer, steam generators, reactor coolant pumps, and control and protection system operations. The LOFTRAN code has been modified, Reference 1, to model heat transfer which may occur in the uncovered tube region of a steam generator and to provide the resultant superheated steam mass and energy releases.

The assumptions used in this analysis were selected to conservatively predict the earliest steam generator tube bundle uncovery time and therfore, the earliest superheat initiation time. The major assumptions to accomplish this purpose are listed below:

a. Primary system temperatures were maximized in order to increase the primary-to-secondary heat transfer. This promotes earlier tube bundle uncovery and maximizes the superheat steam enthalpy following tube bundle uncovery. Assumptions which accomplish this are:

- Maximum temperature error allowances for the initial conditions were assumed.

- The most reactive Rod Cluster Control Assembly is assumed to remain in its fully withdrawn position following reactor trip. This results in a minimum shutdown margin, increasing the possibility and magnitude of a return to criticality and resultant core energy generation during the event.

- 120% ANS (1971) decay heat generation was assumed.

b. Reverse heat transfer from the intact steam generators to the primary system was modeled following steamline isolation. This maintains a maximum primary system temperature throughout the transient.

c. Minimum intial steam generator water levels were assumed to promote early tube bundle uncovery.

d. Maximum feedwater and auxiliary feedwater temperatures were assumed.

e. Feedwater isolation was assumed to occur with minimum delay following a feedwater isolation signal. Continued feedwater flow or feedwater isolation valve failure would result in inventory addition to the steam generator and, therefore, would serve to maintain steam generator level and delay tube bundle uncovery.

f. A limited main feedwater response was used where significant delays in the reactor trip functions occurred. No response was assumed for a minimum of 60 seconds after the initiation of the break. Following this, a slow (linear) response of the feedwater system was assumed which was limited to a maximum of 107% of initial flow for full power cases and to a maximum of 110% of initial flowrate cases initiated at less than full power.

g. A failure of the turbine driven AFW pump was assumed in order to limit mass addition to the steam generators. Auxiliary feedwater flowrates from the motor driven pumps were defined as a function of steam generator pressure. The auxiliary feedwater flowrates which were used take into account the effects of line resistance and differential steam generator pressure on auxiliary feedwater flow.

ANALYSIS RESULTS

Calculations were performed for initial conditions of Full Power, 70% Power. 30% Power and 0% (critical) Power. A spectrum of break sizes ranging from [ ]a,c was investigated for each power level. Figures 1 through 4 summarize the results of the steambreak calculations. These figures show the timing of various safety actuations and the timing of tube bundle uncovery as a function of break size.

The results can be divided into four categories classified by the protection system actuations which occur prior to tube bundle uncovery. Each category defines a range of break sizes which are applicable at a given power level.

1. Reactor Trip, Safety Injection, and Automatic Steamline Isolation

   For the following break sizes, reactor trip, safety injection and steamline isolation occur on a Low Steamline Pressure Signal coincident with a High Steam Flow Signal (LSP/HSF). [ ]a,c A 60 second delay time was used between receipt of the auxiliary feedwater initiation signal and auxiliary feedwater delivery. [ ]a,c

Power Level	Break Size Range (Ft^2)
Full Power	[ ]a,c
70%	
30%	
Hot Zero Power	

For break sizes smaller than the above sizes, a LSP/HSF coincidence does not occur.

2. Reactor Trip and Safety Injection

For the following break sizes, reactor trip and safety injection occur prior to tube bundle uncovery. [

]+a,c

Power Level	Break Size Range (Ft^2)
Full Power	[ ]a,c
70% Power	
30% Power	
Hot Zero Power	

3. Reactor Trip, Safety Injection, and Manual Steamline Isolation

For the following break sizes, reactor trip and safety injection occur prior to tube bundle uncovery. In addition, manual steamline isolation at 10 minutes will occur prior to tube bundle uncovery.

Power Level	Break Size Range (Ft^2)
Full Power	[ ]a,c
70% Power	
30% Power	
Hot Zero Power	

4. No Protection/Safeguards Actuation

For these cases, the main feedwater system maintains the tubes covered and only saturated steam releases result until after operator action is taken. The net result for these cases is an increased steam load on the plan corresponding to the break flow. The break sizes below which no safety actuations occur, due to the capability of the feedwater system to compensate for the increased steam flow, depend upon both the feedwater control system capabilities and the initial conditions of the plant. The approximate break ranges for the Full Power, 70%, 30%, and 0% Power cases are given below:

Power Level	Break Size Range (Ft^2)
Full Power	[ ]a,c
70% Power	
30% Power	
0% Power	

Break sizes in the range identified above are assumed to be dependent upon operator action to terminate the break release. The mass/energy releases will be limited to saturated steam until after operator action occurs.

MASS/ENERGY RELEASES

Tables 1 through 12 provide mass and energy release data for 30%, 70%, and Full Power cases. All cases initiated from 0% (critical) either resulted in an insignificant amount of superheat being generated or were bounded by the results for the higher power cases. Tables 1, 2, and 3 provide mass/energy release data for a[ ]break initiated at Full Power, 70% Power, and 30% Power respectively. For these cases,[

]a,c Tables 4, 5, and 6 provide mass/energy release data for the smallest break size in which an automatic steamline isolation signal is obtained. The data in the tables however reflect mass/energy releases without automatic steamline isolation. These cases were performed to provide bounding mass/energy release data for cases in which an automatic steamline isolation signal is not obtained. Tables 5 through 12 provide mass/energy release data for[ ]a,c breaks initiated at 30%, 70%, and Full Power.

For cases in which greater than [

]b,c Tables 4 through 9 and 12 provide mass/energy release data [

]a,c

REFERENCES

1. Osborne, M. P., Love, D. S., "Mass and Energy Releases Following A Steamline Rupture, Supplement 1 - Calculations of Steam Superheat In Mass/Energy Releases Following A Steamline Rupture," WCAP-8822-P-S1 (Proprietary), January 1985.

TABLE 1

WATTS BAR MASS/ENERGY RELEASES

FULL POWER - [ ]+a,c STEAMLINE BREAK

a, b, c

THIS TABLE IS CONSIDERED PROPRIETARY IN ITS ENTIRITY

TABLE 2

WATTS BAR MASS/ENERGY RELEASES

+a,c

70% POWER - [ ] STEAMLINE BREAK

a,b,c

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TABLE 3

WATTS BAR MASS/ENERGY RELEASES

30% POWER - [ ]+a,c STEAMLINE BREAK

+a,b,c

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TABLE 4

a, b, c

WATTS BAR MASS/ENERGY RELEASES

FULL POWER - [ ] +a, c STEAMLINE BREAK

THIS TABLE IS CONSIDERED PROPRIETARY
IN ITS ENTIRITY

TABLE 5

WATTS BAR MASS/ENERGY RELEASES

70% POWER -[ ]+a,c STEAMLINE BREAK

a,b,c

THIS TABLE IS CONSIDERED PROPRIETARY
IN ITS ENTIRITY

TABLE 6

WATTS BAR MASS/ENERGY RELEASES

30% POWER -[ ]+a,c STEAMLINE BREAK

a,b,c

THIS TABLE IS CONSIDERED PROPRIETARY
IN ITS ENTIRITY

TABLE 7

a, b, c

WATTS BAR MASS/ENERGY RELEASES

+a,c

FULL POWER - [ ] STEAMLINE BREAK

THIS TABLE IS CONSIDERED PROPRIETARY
IN ITS ENTIRITY

TABLE 8

WATTS BAR MASS/ENERGY RELEASES

+a,c

70% POWER -[ ]STEAMLINE BREAK

a,b,c

THIS TABLE IS CONSIDERED PROPRIETARY
IN ITS ENTIRITY

TABLE 9

a, b, c

WATTS BAR MASS/ENERGY RELEASES

30% POWER - [ ]+a,c STEAMLINE BREAK

THIS TABLE IS CONSIDERED PROPRIETARY
IN ITS ENTIRITY

TABLE 10

a,b,c

WATTS BAR MASS/ENERGY RELEASES

+a.c.

FULL POWER -[ ]STEAMLINE BREAK

THIS TABLE IS CONSIDERED PROPRIETARY
IN ITS ENTIRITY

TABLE 11

WATTS BAR MASS/ENERGY RELEASES

70% POWER - [ ]+a,c STEAMLINE BREAK

a,b,c

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TABLE 12

WATTS BAR MASS/ENERGY RELEASES

30% POWER - [ ] STEAMLINE BREAK

a, b, c

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FIGURE 1

WATTS BAR STEAMBREAK INITIATED AT FULL POWER

SAFETY SYSTEM ACTUATION AND TUBE BUNDLE UNCOVERY TIMES

AS A FUNCTION OF HEADER BREAK AREA

a,b,c

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FIGURE 2

WATTS BAR STEAMBREAK INITIATED AT 70% POWER

SAFETY SYSTEM ACTUATION AND TUBE BUNDLE UNCOVERY TIMES

AS A FUNCTION OF HEADER BREAK AREA

a,b,c

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FIGURE 3

WATTS BAR STEAMBREAK INITIATED AT 30% POWER

SAFETY SYSTEM ACTUATION AND TUBE BUNDLE UNCOVERY TIMES

AS A FUNCTION OF HEADER BREAK AREA

a,b,c

THIS FIGURE IS CONSIDERED PROPRIETARY IN ITS ENTIRITY

FIGURE 4

WATTS BAR STEAMBREAK INITIATED AT 0% POWER

SAFETY SYSTEM ACTUATION AND TUBE BUNDLE UNCOVERY TIMES

AS A FUNCTION OF HEADER BREAK AREA

a,b,c

THIS FIGURE IS CONSIDERED PROPRIETARY
IN ITS ENTIRITY