CONF-840614--17

RELAP/FRAP-T6 ANALYSIS OF SEIZED AND SHEARED SHAFT ACCIDENTS*

J. S. Bollinger
Toshikazu Ito
G. B. Peeler

CONF-840614--17
DE84 006470

Reactor Analysis and Safety Division
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

Argonne National Laboratory (ANL) performed audit calculations of a Reactor Coolant Pump (RCP) seized/sheared shaft transient for the Westinghouse Seabrook Plant using RELAP5/MOD 1.5 (Cycle 32) and FRAP-T6. The objective was to determine the effect of time of loss of offsite power and other single component failures on the peak clad temperature. The RCP shaft seizure event was modeled in RELAP5 by using the pump model shaft stop option. In modeling the sheared shaft failure, the faulted pump was replaced with a branch component having no flow losses.

In general, the RELAP5-predicted system response for the seized shaft transient was very comparable to the results presented in the Seabrook FSAR, although the Reactor Coolant System (RCS) pressure response was somewhat different. Apparently, Westinghouse used the ideal gas law to determine the maximum pressure, while RELAP5 uses an equation of state. For the seized shaft transient with offsite power unavailable, losing offsite power concurrently with the shaft failure produces the most adverse core flow response.

The RELAP5 sheared-shaft analysis results were very similar to those for the seized shaft. The initial rate of reduction of coolant flow was greater for the seized shaft event. However, as expected, the sheared shaft event

---

[*] Work performed under the auspices of the USNRC Division of Systems Integration.

permitted a greater amount of reverse flow through the faulted loop later during the transient, which resulted in a lower core flow at that time.

In examining the impact of single component failures, the only realistic failure assumption is that a power operated relief valve (PORV) or safety valve opens and then remains stuck open. Assuming PORV failure did not significantly effect the predicted peak cladding temperature during either of the transients considered.

RELAP5 analyses provided the boundary conditions (coolant flowrate, coolant inlet enthalpy vs. time, and reactor coolant pressure vs. time) for the FRAP-T6 analyses, which were used to determine the peak cladding temperature. In some cases analyzed, the pressure was assumed to remain constant at the initial value to maximize cladding temperatures and investigate the sensitivity of the results to pressure.

Two FRAP-T6 categories were defined; operation with a hot rod power of 12.9 kw/ft, and operation where the operator has failed to take action to correct a flux difference violation (hot spot rod power of 18 kw/ft).

Westinghouse made the assumption that film boiling was initiated at the start of the transient. In order to simulate this for the first category, a boundary condition switch was activated which forced the code to apply film boiling correlations and logic at the transient initiation, even though film boiling would not have been predicted to occur until several seconds into the transient. In the second category, the fuel rod was predicted to be operating in film boiling prior to reaching the initial power level. To accommodate the Westinghouse assumption that the fuel rod experienced film boiling at the start of the transient, the following unique procedure was developed.

First: The fuel rod was initialized at 18 kw/ft at the hot spot and the temperatures were allowed to equilibrate.

Second: Starting from the equilibrated condition, the flow was coasted down. This defined an axial region which could be expected to experience film boiling during the various cases considered.

Third: A CHF multiplier was utilized which prohibited the internal code logic from predicting film boiling. A boundary condition switch was then activated which forced the code to predict film boiling at those nodes determined in the second step.

Fourth: To assess whether or not film boiling quenching would occur, the first and second steps are used and the transient analyzed. If quenching is predicted to occur in this analysis, where the fuel rod temperatures have equilibrated with film boiling boundary conditions; then it is postulated that quenching would have occurred during the transient where film boiling was specified to occur at time zero.

Table 1 summarizes the peak cladding temperatures that were obtained for the various cases analyzed.

In summary,

- The most limiting transient in terms of peak cladding temperature with and without a loss of offsite power was the sheared shaft transient.
- The most adverse time of loss of offsite power was concurrently with shaft failure.
- The initial value for the faulted loop flow had an insignificant impact on the predicted time of reactor trip.
- The effect of PORV failure on the maximum cladding temperatures was minimal.
- The RELAP5 results and the Westinghouse Seabrook FSAR showed an almost identical core and faulted loop flow response.

- The initial rate of reduction of coolant flow was greater for the seized shaft event, and as expected, the sheared shaft event permitted more reverse flow through the faulted loop later during the transient.
- The primary system pressure response showed RELAP5 maximum pressures approximately 100 psi less than the Westinghouse FSAR results.
- Long term core coolability is assured since the predicted time at temperature during film boiling was insufficient to cause brittle fracture of the cladding upon rewet.

Therefore, it was concluded that the Westinghouse reported value of peak cladding temperature (~ 1700°F) for the seized/sheared shaft event represents a very conservative upper limit for the peak cladding surface temperature that might be expected for operation at 12.9 kw/ft and a slightly conservative value for assumed operation at 18 kw/ft. Finally, the two cases shown in Table 1, where the gap conductance and surface heat transfer coefficient were set to values of 10,000 and 200 BTU/hr$\cdot$ft^{2}°F, respectively, provided additional confirmation concerning the conservatism in the Westinghouse reported value of peak cladding temperature.

Table 1. Summary of Seized/Sheared Shaft Peak Cladding Temperatures

Peak Cladding Temperature (°F)	Transient Description
988.0*	Operation at 12.9 kw/ft, seized shaft, pressure constant, FRAP-T6 predicted film boiling
1103.2*	Operation at 12.9 kw/ft, seized shaft, pressure constant, specified boiling zone
1278.0**	Operation at 12.9 kw/ft, seized shaft, pressure constant, specified film boiling.
1460.0***	Operation at 12.9 kw/ft, seized shaft, pressure constant, specified film boiling
1433.0****	Equilibrium operation at 18 kw/ft
1500.2****	Seized shaft, pressure versus time
1582.2****	Seized shaft, pressure constant
1618.1****	Seized shaft, loss of offsite power, pressure constant
1592.5****	Seized shaft, loss of offsite power, pressure versus time, PORV failure
1595.9****	Sheared shaft, pressure constant
1515.7****	Sheared shaft, pressure versus time, PORV failure
1621.3****	Sheared shaft, loss of offsite power, pressure constant
1600.4****	Sheared shaft, loss of offsite power, pressure versus time, PORV failure

* Hot spot film boiling node at 9.9 kw/ft.

** Hot spot film boiling node at 9.9 kw/ft, gap conductance 10,000 BTU/hr·ft^2°F, surface heat transfer coefficient 200 BTU/hr·ft^2°F.

*** Hot spot film boiling node at 12.9 kw/ft, gap conductance 10,000 BTU/hr·ft^2°F, surface heat transfer coefficient 200 BTU/hr·ft^2°F.

**** Hot spot film boiling node at 18 kw/ft.