NUCLEAR REACTOR SURGE TANK PRESSURE TRANSIENTS

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With the advent of nuclear reactor power plants, the development of a rigorous theoretical model for predicting steam surge tank pressure transients during prescribed changes in liquid level history has been a subject of great interest. Surge tanks are located in the primary loop of a reactor. Liquid is heated in the reactor core and flows through a steam generator where steam is generated and sent to the turbine system. Primary coolant temperature tends to shift with the changing turbine load, which in turn causes volume transients. The chamber providing the required expansion volume is called a surge tank or pressurizer. It serves a dual function. It provides a means to control the system pressure, as well as allowing the liquid thermal expansion, by admitting more fluid.

There are three distinct modes of surges of current interest, namely, outsurge, insurge, and multiple surge (a series of insurges and outsurges). Multiple surges may occur when a power plant experiences large fluctuations in power demand. The "pure" outsurge and "pure" insurge have been dealt with successfully by various investigators using different approaches (1-3). A brief outline of the theoretical models for the three modes of surges is given herein.

(1) Pure Outsurge:

During outsurge, there always exists a thermodynamic equilibrium between the phases and both the vapor and liquid remain in saturation condition. Heat transfer between the system and the pressurizer wall will be through sensible heat transfer only and because this is a relatively poor mechanism of heat transfer, its effect is completely neglected and the process is assumed to be adiabatic.

Starting with the continuity and the energy equations the relationship between the liquid level history in a surge tank and the corresponding vapor pressure drop can be obtained (3).

(2) Pure Insurge:

When an insurge to the pressurizer occurs, vapor temperature and pressure begin to rise. As a result, the vapor condenses on the cooler boundary surfaces and heat is transferred to the vessel wall and liquid in the pressurizer. Starting with the same equations of continuity and energy, the relationship between the tank pressure and the liquid level history was derived (3):

$$\frac{dp}{dt} = \frac{pkb\dot{L} + pk\left(\frac{\partial v_{sus}}{\partial h_{sus}}\right)_p \left(\frac{dQ}{dt}\right)}{V_d - a - bL}$$

where $\frac{dQ}{dt}$ is the rate of heat transfer and is computed by solving the Fourier equation of transient heat conduction through the wall (3).

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Results of a typical run are shown in Fig. 1. It is clear from the figure that the predicted pressure is in close agreement with experiment (4).

(3) Multiple Surge:

Utilizing the solution for outsurge and insurge and with proper modifications, an analysis was performed on a sinusoidal type of multiple surge (3,5). Two cases of multiple surge were investigated, namely: Case 1, outsurge followed by insurge and; Case 2, insurge followed by outsurge. Extension of these cases to other more complicated multiple surges was also attempted. The predicted pressure history of the multiple surge process seems reasonably good but as one might anticipate, further experimental verifications are required.

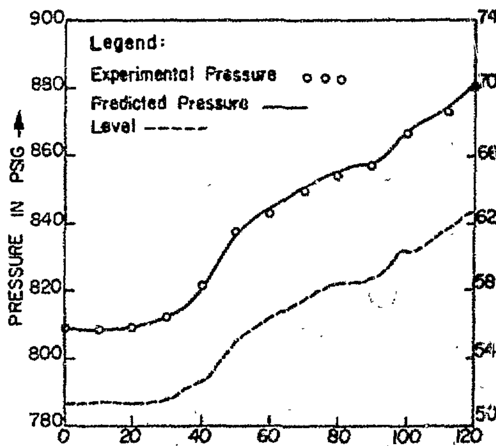

FIG. 1 COMPARISON BETWEEN PREDICTED PRESSURE HISTORY WITH EXPERIMENTS FOR RUN NO. 6

The associated governing equations from our surge tank studies were mostly solved via the IBM/CSMP package. Because of its easy accessibility and relative ease of use (e.g. free from scaling), CSMP has gained wide acceptance as an important tool in dealing with engineering problems.

Experimental studies are very important in this study, both for checking the analytical model and for obtaining a better understanding of certain phenomena occurring in the surge tank. A pilot project of constructing a small surge tank testing facility has therefore been initiated. Work will be continued to develop a generalized model for surge tanks involving multiple piping inlets and outlets such as the one associated with Gentily Power Plant, P.Q. Closely allied problems, for example the pressure response to surges in air surge tanks attached to large hydraulic ducts, etc., will also be explored.

References:

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