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Technical Bulletin **No. 0497-1**

Resolution of Generic Letter 96-06 Thermal Hydraulic Issues

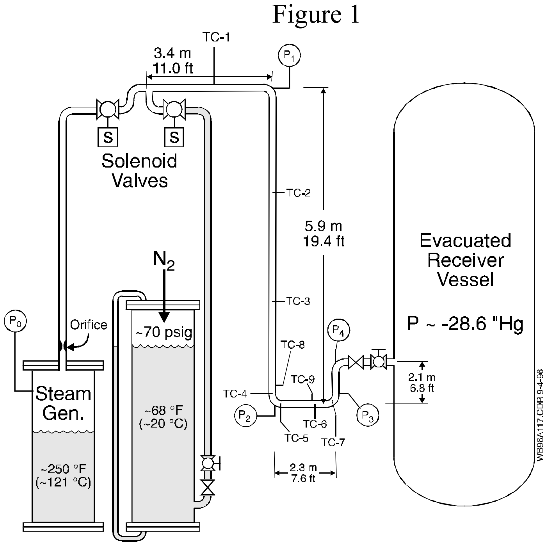
BACKGROUND

Late in 1996, the U.S. NRC issued Generic Letter GL 96-06; *Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions (September 30, 1996).* To date, most U.S. nuclear utilities have demonstrated short-term operability as part of their 120 day responses to GL 96-06, but may still have to address longer-term issues such as:

1. heat removal from containment fan coolers (or other safety related heat exchangers) under two-phase flow conditions
2. containment fan cooler performance following pump restart; and
3. ability of pipe hangers and restraints to handle dynamic loading due to condensation and column-rejoining-induced waterhammer events.

Recent experimental and theoretical investigations performed by Fauske & Associates, Inc. (FAI) facilities have been applied at several nuclear power plants to provide resolution to these long-term operability issues.

Figure 1



EXPERIMENTAL STUDIES

Figure 1 depicts one arrangement of the test apparatus used at the FAI facility to perform scaled experiments of containment fan cooler two-phase flow and waterhammer phenomena. This configuration represents a fan cooler located at an upper elevation in containment. By alternately injecting cold water and steam into the elevated sections of the test apparatus, FAI was able to successfully create the column separation, column rejoining, and steam condensation process for a range of realistic, scaled accident conditions.

FAI's experimental investigations have provided crucial information regarding the relevant physical processes surrounding the voiding and refilling of heat exchanger piping, and have also led to insights related to:

1. The dynamic loads resulting from waterhammer events.
2. The influence of non-condensable gases on load magnitude.
3. The impact of wall heat transfer on flow regimes during refill.

These insights have subsequently been incorporated into FAI's TREMOLO computer program, which provides best estimate analysis of pipe line two-phase thermal hydraulic transients and waterhammer-induced forcing functions.

TREMOLO COMPUTER CODE

FAI's TREMOLO computer program has been used to analyze two-phase flow in the service water piping of nuclear power plants in response to NRC Generic Letters 89-10 and 96-06. These analyses have focused on two-phase flow heat transfer in containment fan coolers, waterhammer effects due to steam condensation and water column rejoining, and pipe wall thermal response for insulated and uninsulated piping inside containment.

To support these applications, the TREMOLO code has been validated with benchmarks against available data. These benchmarks have been performed in accordance with FAI QA procedures which meet 10 CFR50 Appendix B, ISO-9001 and ASME NQA-1 requirements.

A sample TREMOLO benchmark, presented in Figure 2, compares the experimental data of G. Cerne, et al., against RELAP and TREMOLO transient calculations. Key features of the experiment include initial water temperature and pressure of 325°F and 145 psia, respectively, and an instantaneous closure of a valve 120 feet downstream from the pipe inlet. The data in Figure 2 represent the pressure at the valve inlet. As shown, the TREMOLO calculations bound the peak dynamic pressure at the valve inlet.

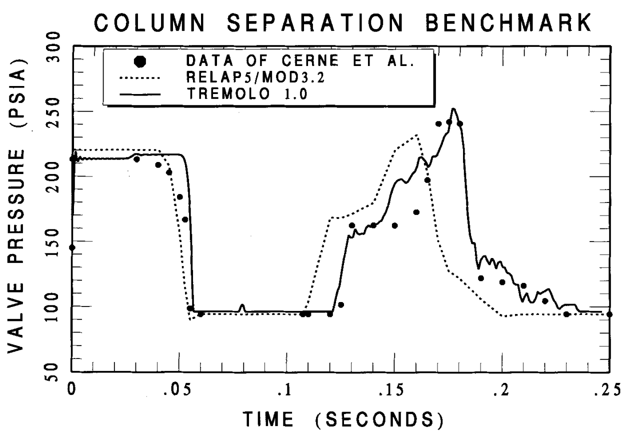


Figure 2

Real plant applications are complicated by several factors. Typically, the service water supply and return piping for a containment fan cooler may include 1000 feet of pipe, with several changes in pipe diameter and upwards of 100 different elbows, tees, expansions, and valves. In contrast, the dynamic loads of interest may occur in only a few feet of the 1000 foot circuit and affect only a handful of the piping elements. Also, while the transient of interest unfolds over 60 seconds, or more, the dynamic effects occur on a millisecond time scale.

The TREMOLO code overcomes these difficulties in scale by providing a fast-running code architecture, input flexibility to model the important details of the pipe circuit, and modeling capabilities based on experimental investigations conducted by FAI and available in the open literature.

PLANT APPLICATIONS

TREMOLO transient analyses of loss of offsite power sequences with and without a coincident LOCA have been applied at a number of nuclear power plants in support of GL 96-06 issue resolution. These studies have consistently indicated that:

1. soon after pump restart, single phase liquid flow is reestablished to the containment fan coolers, therefore long-term containment heat removal is not impaired;
2. the best estimate of waterhammer pressure loads following pump restart would not be large enough to threaten the structural integrity of safety-related piping; and
3. the fundamental TREMOLO results are consistent with insights gained from FAI's experimental investigations into containment fan cooler two-phase flow and waterhammer phenomena.

Results from the TREMOLO analysis (i.e., the two-phase fan cooler heat transfer, pipe wall thermal response, and pipe hanger forcing functions) are typically coupled with a transient structural analysis to provide final resolution to the operability issues related to GL 96-06.

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