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Technical Bulletin **No. 0600-1**

Prediction of Control Valve Capacities under Flashing Flow Conditions

BACKGROUND

For conditions of interest in design basis behavior such as those listed in NRC Generic Letter 96-06, *Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions (September 30, 1996),* the flow through control valves in the cooling circuits for safety grade fan coolers could experience two-phase flow and potentially limitations due to two-phase critical flow.

To improve the resolution and application of two-phase techniques to such control valve behavior, an experiment has been performed to measure the two-phase critical flow rate through a globe valve.

VALVE CAPACITY FOR ALL-LIQUID FLOW

Valve manufacturers provide valve flow coefficients, C_v, based on single-phase liquid test measurements. When this information is available, as shown in Figure 1, the valve capacity can be readily determined from the following equation,

$$Q = C_V \sqrt{\Delta P \cdot \frac{\rho_{ref}}{\rho}} \quad (1)$$

where Q is the volumetric flow rate (gpm), ΔP is the pressure drop across the valve (psi), ρ_{ref} is the fluid density at which the test measurements were taken, and ρ is the current fluid density.

TWO-PHASE FLOW CONSIDERATIONS

If saturated or slightly subcooled water passes through a globe valve, the ensuing pressure drop may result in a two-phase flow condition. Once this occurs, the flow rate is limited by critical flow considerations, which are dependent on the sonic velocity through the two-phase mixture. Thus, for two-phase critical flow, the flow rate is not determined by the total pressure drop across the valve.

This implies that an equivalent C_v for two-phase flow cannot be applied directly with Equation (1) to determine the valve capacity. However, if the manufacturer's single-phase liquid C_v data is used in combination with a valid two-phase critical flow model, then valve capacities under flashing flow conditions can be accurately predicted, as discussed below.

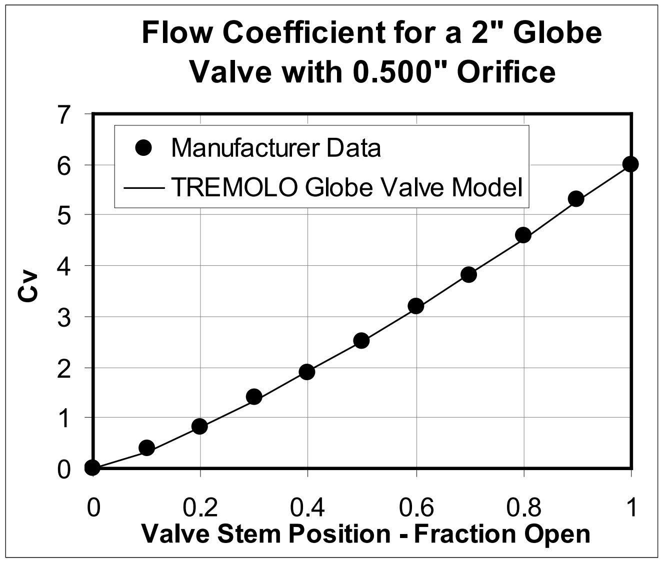

Figure 1 Comparison of TREMOLO Revision 3 Globe Valve Power Law Model against Manufacturer Data for a 2-Inch Globe Valve with a 0.500-inch Orifice.

EXPERIMENTAL AND ANALYTICAL STUDIES

A series of experiments was performed under single- and two-phase flow conditions to measure the flow rate through a 1" globe valve over a range of valve stem positions. Figure 2 is a schematic of this test facility, which includes measurements of pressure, temperature, flow rate and valve stem position. Test data was reduced to determine the single-phase valve flow coefficient, the fluid flow rates, and the fluid density (for the two-phase flow tests).

Many of the single-phase tests were repeated with saturated or slightly subcooled water such that flashing flow resulted across the globe valve. Several of the test runs experiencing flashing flow were then analyzed with FAI's TREMOLO computer code.

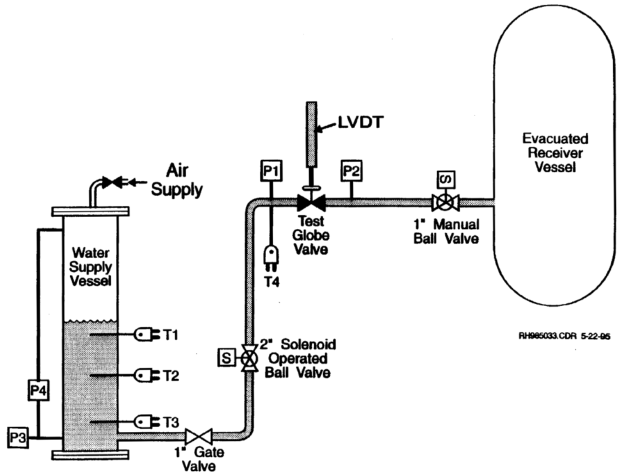

Figure 2 FAI Test Apparatus for Flashing Flow Experiments on 1" Globe Valves

The TREMOLO computer code is designed to analyze two-phase flow transients in power plant piping systems. TREMOLO 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 valve closing differential pressure, throttle valve flashing flow, 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.

For tests with similar valve stem positions, the single-phase C_v value was input to TREMOLO 3.0 along with the hot fluid temperature and the measured upstream and downstream pressures. TREMOLO steady state calculations were then performed to predict the two-phase mass flow rate through the globe valve.

Figure 3 compares the TREMOLO calculation of flashing flow through the globe valve to the test data over a range of valve stem position from 10% to 62% open. In general, the TREMOLO calculation matches the test data although in some cases the TREMOLO calculation overpredicts the two-phase mass flow rate.

CONCLUSIONS

Because the critical flow limitations uncouple the upstream and downstream pressures, Equation (1) cannot be applied directly with an equivalent C_v for two-phase flow. Rather, as is done in the TREMOLO calculation, the single phase flow coefficients should be used to characterize the valve hydraulic resistance and this should be coupled with an appropriate two-phase critical flow model, such as the Henry-Fauske model used in TREMOLO, to obtain reasonable results.

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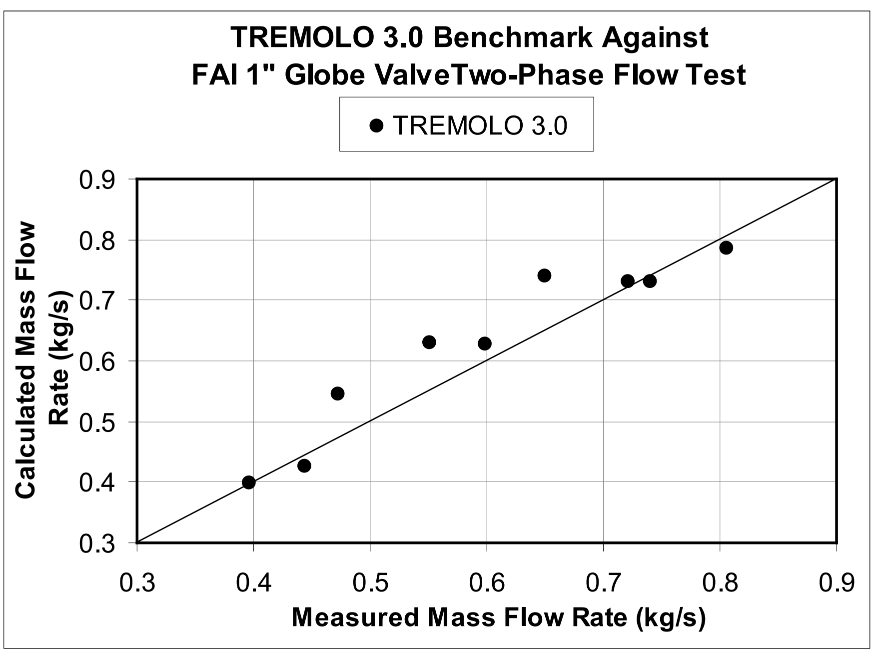

FIGURE 3 Comparison of TREMOLO 3.0 calculations against FAI 1" Globe Valve Two-Phase Flow Tests