Conditions of Fluid in RHR Line after Loss and Restart of RHR pump at Turkey Point 3 (DRAFT)

By

Joe Miller
EDA, Inc

2015 Woodford Rd.
Vienna, Virginia 22182
www.edasolutions.com

Introduction

Due to a recent outage event at Turkey Point Unit 3, a loss of shutdown cooling occurred during reduced RCS inventory conditions. The head was still on the vessel. GOTHIC (Ref. 1) was used to evaluate the system response. The GOTHIC evaluation showed the possibility of voids in the Hot Leg C piping where the RHR pump takes suction for shutdown cooling. A system diagram is shown in Figure 1. The concern was raised that the RHR pumps may not operate with voids in the Hot Leg C piping. To provide evidence that the RHR pumps will operate with some voiding in the Hot Leg C piping, a RELAP5 model of the RHR piping was constructed.

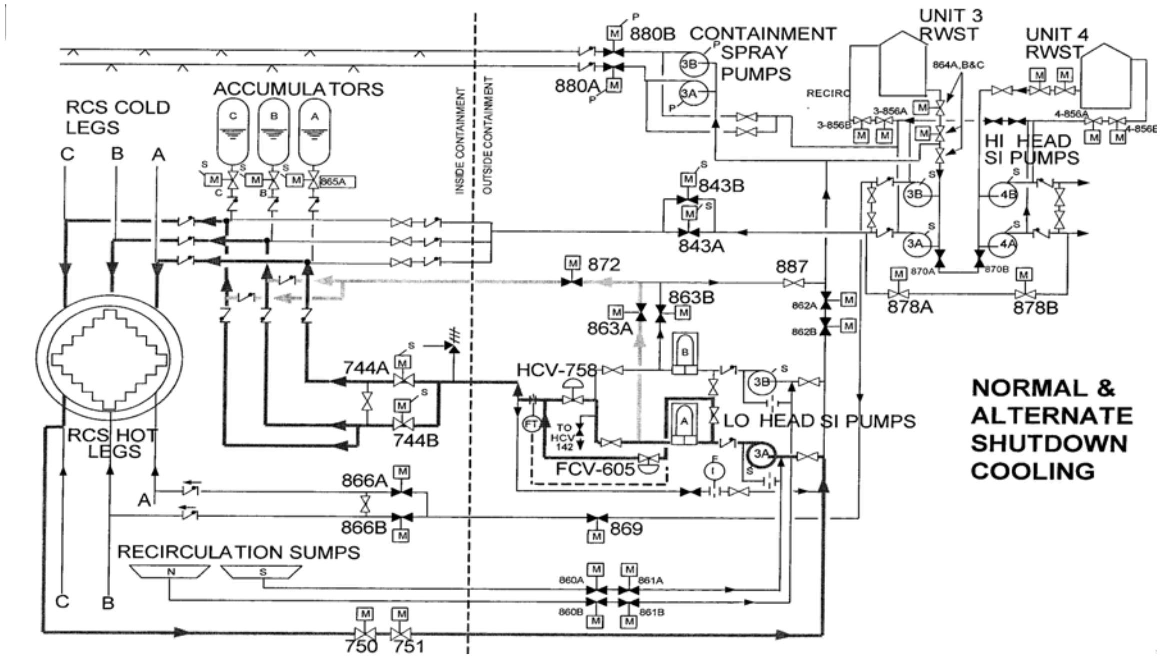

Figure 1 Shutdown Cooling

1. Description of Model

A RELAP5/M3.3 model was constructed to simulate the fluid in the RHR line from the Hot Leg C to the RHR pump (3P210A). RELAP5/M3.3 (Ref. 2) is a computer code used for the thermal-hydraulic analysis of transients and small-break accidents and transients in light-water nuclear power plants. RELAP5 uses a one-dimensional, two-fluid model, consisting of steam and water, with the possibility of the vapor phase containing a non-condensable component. The RELAP5 program has been used to solve similar problems to the RHR flow problem (Refs. 3 &4) and has been validated for calculating fluid flow conditions and resulting forcing functions (Ref. 5).

The RELAP5 model was constructed for the RHR system and is shown in Figure 2. The model begins from the Hot Leg C (RELAP5 component 104), which is a 30-inch pipe leaving the reactor vessel. The 14-inch Residual Heat Removal (RHR) connects to the Hot Leg C through junction 401 and traverses to RHR pump 3P210A (RELAP5 Component 201) as shown in the diagram in Figure 2.

The model consists of two pumps, i.e., RHR pumps 3P210A and 3P210B. For these simulations, pump 3P210B (RELAP5 Component 202) was not started. The pumps rated head is 210 feet at a rated flow of 3500 gpm. Two motor operated valves (MOVs), MOV-3-751 and MOV-3-750 were also modeled. Loss coefficients and sizes were taken from References 6, 7 & 8. At time equal zero, the RHR 14” piping is full of 120° F water. The 14” pipe running from the Hot Leg C to pump 3P210A is about 190 feet in length.

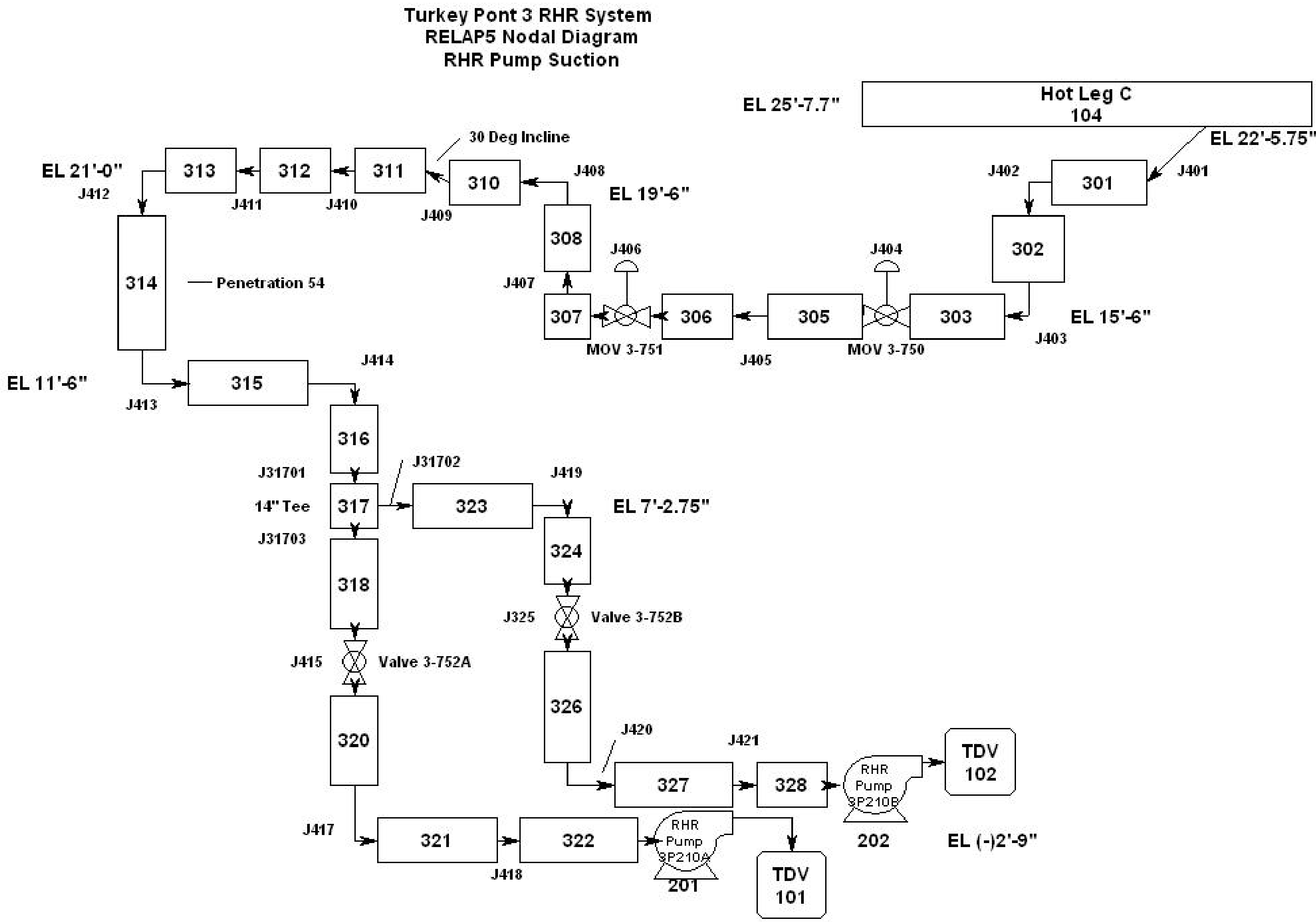

Figure 2 RELAP5 Nodal Diagram of RHR System

2. Results

Four cases were analyzed with RELAP5. The first case simulated saturated conditions at 55 psia in the Hot Leg C pipe with the 3P210A pump running at a rated flow of 3500 gpm at rated density. The second case was to simulate slightly less than 10 voids in the Hot Leg C piping at 55 psia. The third case was to simulate 30% voids in the Hot Leg C piping at 55 psia and the fourth case was to simulate greater than 40% in the Hot Leg C piping at 55 psia.

Figure 3 shows the pressure distribution in the RHR piping for the saturated liquid at 55-psia case. Figure 3 shows that the pressure in the piping leading to the pumps is about 64 psia whereas the pressure at the 14" pipe inlet from the Hot Leg C is about 54 psia. The elevation head change and pressure drops from form losses cause the pressure differences from the Hot Leg C to the pump inlet.

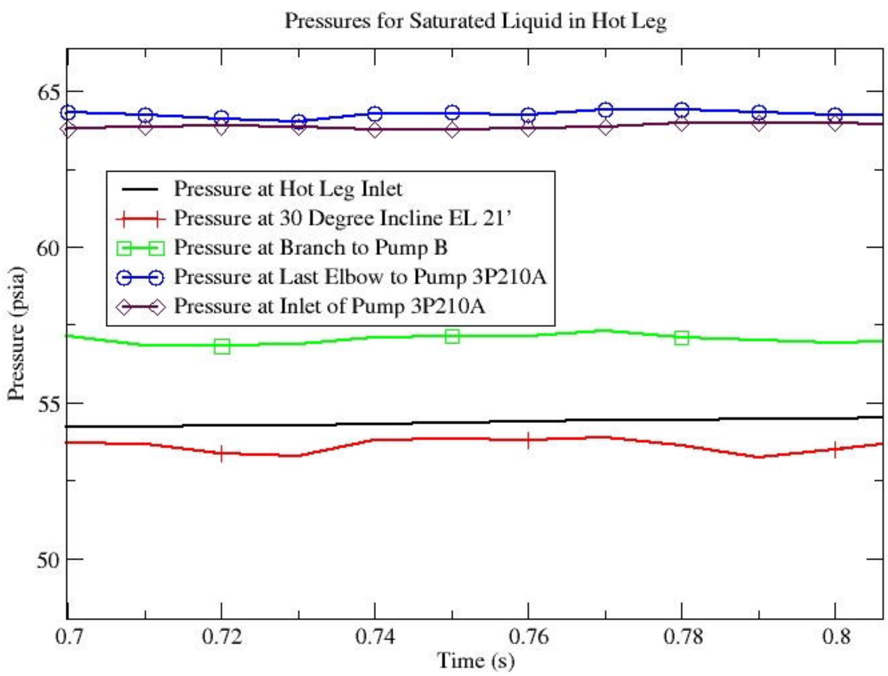

Figure 3 Case 1 Pressures for Saturated Liquid in Hot Leg C

Figure 4 shows the densities in the RHR piping for the saturated liquid case after the cool water (120° F) has been flushed through the pump. The density in the Hot Leg C piping (i.e., RELAP5 Component 104) is approximately 57 lbm/ft^3. The density in the 14" RHR inlet piping (RELAP5 Component 301) reduces due to the pressure drop from the Hot Leg C to the 14" pipe. The density reduces further as the fluid traverses along the horizontal piping and up the 30° incline at Elevation 21 feet. Once the fluid flows down into the lower elevation of the pumps (RELAP5 Components 320 and 322), the density increases above the saturated density of the Hot Leg C (RELAP5 Component 104).

Figure 4 shows the voids in the 14" RHR pipe inlet for the 4 cases. Case 1 assumes saturated liquid in the Hot Leg C, Case 2 assumes slightly less than 10% voids in the Hot

Leg C, Case 3 assumes 30 % voids in the Hot Leg C and Case 4 assumes greater than 40% voids in the Hot Leg C.

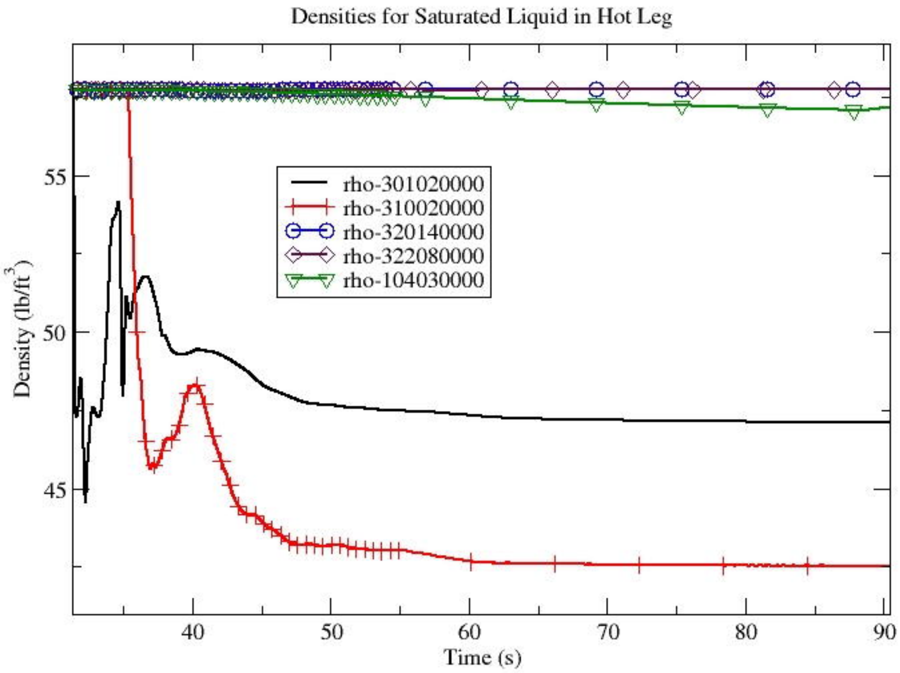

Figure 4 Densities for Saturated Liquid in Hot Leg C

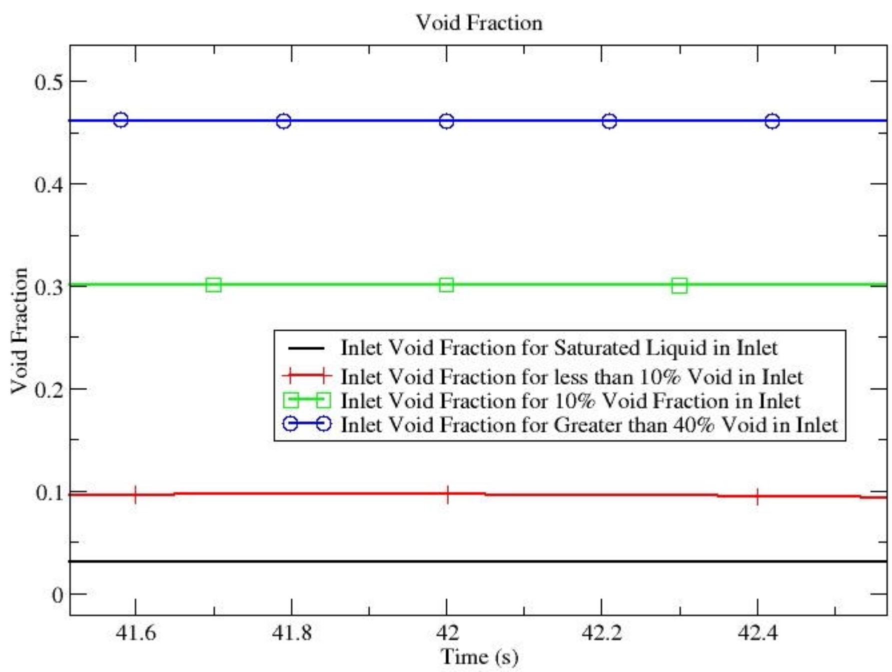

Figure 5 Voids in the 14” RHR Inlet for the 4 Cases Simulated

Figure 6 shows the density at the RHR pump inlet for each of the cases simulated. For Cases 1, 2 and 3 (i.e., saturated liquid in Hot Leg C, less than 10% voids in hot let and 30% voids in Hot Leg C, respectively), the density at the RHR pump inlet was calculated as 58 lbm/ft^3. For Case 4, the greater than 40% voids in the Hot Leg C case, the density was calculated to be .25 lbm/ft^3 and the pump failed.

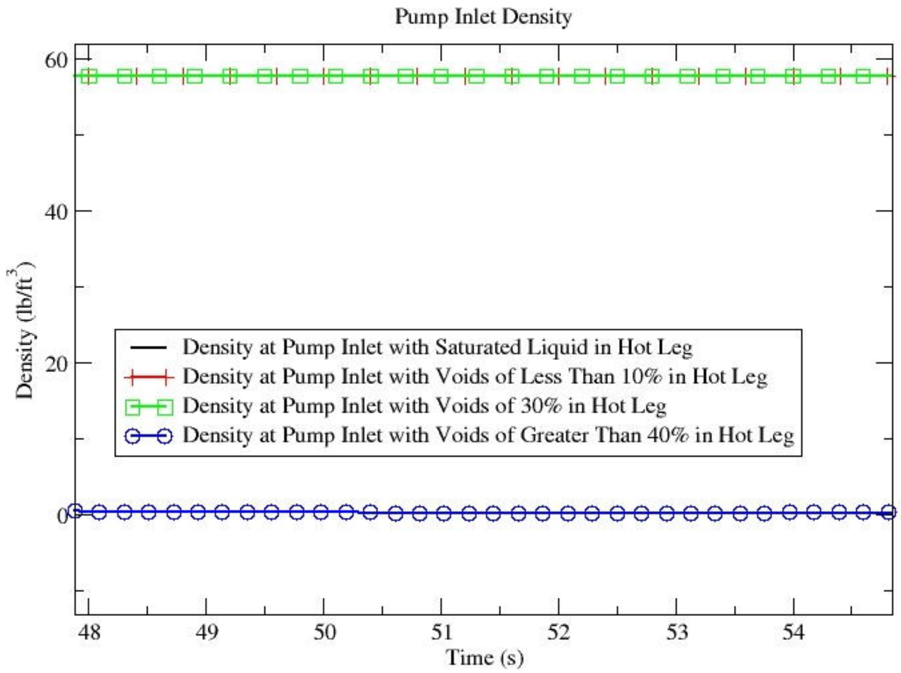

Figure 6 Density in the 14" RHR Pump Inlet for the 4 Cases Simulated

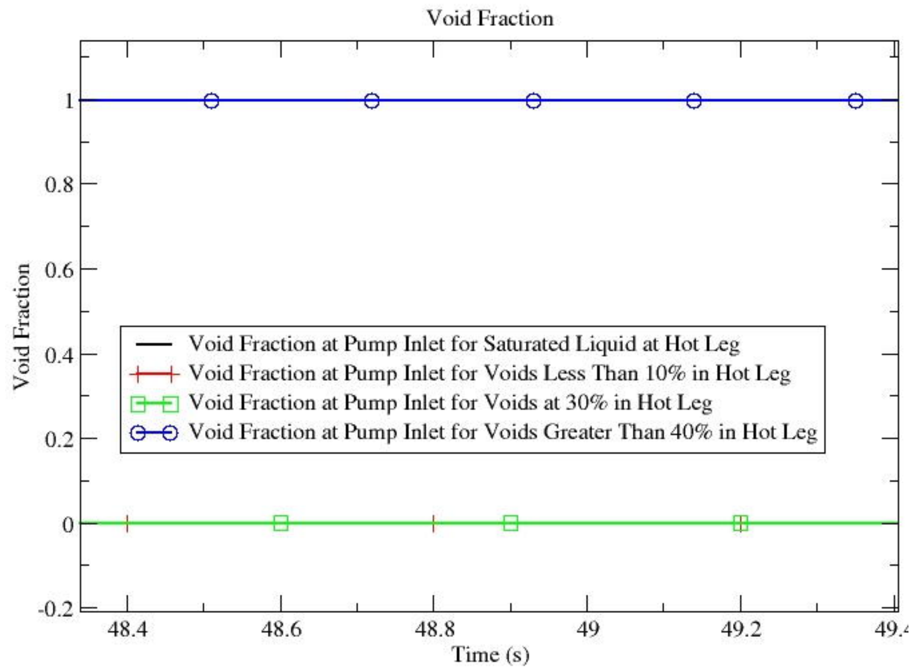

Figure 7 Voids in the 14" RHR Pump Inlet for the 4 Cases Simulated

Figure 7 shows the gas void at the RHR pump inlet for each of the cases simulated. For Cases 1, 2 and 3 (i.e., saturated liquid in Hot Leg C, less than 10% voids in hot let and 30% voids in Hot Leg C, respectively), the void at the RHR pump inlet was calculated as 0.0. For Case 4, the greater than 40% voids in the Hot Leg C case, the Void was calculated to be 1.0 and the pump failed.

Table 1 presents the results of the 4 cases simulated. Cases 1, 2 and 3 that represented up to 30% voiding in the Hot Leg C, indicated that no voiding occurred in the pump inlet. Case 4, which represented the simulated case with greater than 40% voids in the Hot Leg C, showed that the pump inlet would be completely voided with no flow through the pump.

Table 1 Summary of the Cases

RELAP5 Case	Description	RELAP5 File	Voids in Hot Leg C	Voids at Pump 3A Inlet
1	Saturated Liquid in Hot Leg C	RHRpg.i	None	None
2	Less Than 10% Voids in Hot Leg C	RHRpd.i	Less Than 10% Voids	None
3	30% Voids in Hot Leg C	RHRpe.i	30% Voids	None
4	Greater Than 40% Voids in Hot Leg C	RHRpf.i	Greater Than 40% Voids	100% Voiding

3. Conclusions

Four cases were simulated with RELAP5. Case 1 simulated saturated conditions at 55 psia in the Hot Leg C pipe. Case 2 simulated slightly less than 10 voids in the Hot Leg C piping at 55 psia. Case 3 simulated 30% voids in the Hot Leg C piping at 55 psia and Case 4 simulated greater than 40% in the Hot Leg C piping at 55 psia. For all cases, the 3P210A pump was running at a rated flow of 3500 gpm at rated density.

The results indicated that for voids 30 % or less in the Hot Leg C, the RHR pump would have adequate suction flow to remain in a stable operational condition.

4. References

1) Letter from Jim Harrell, Vice President – Eastern Division, to Mr. Jose Garcia, FP&L, "Turkey Point Unit 3 Loss of Decay Heat Removal", September 26, 2006.
2) NUREG/CR-5535/Rev1, RELAP5/MOD3.3 VOLUMES 1 through 8, Prepared by Information Systems Laboratories, Inc., Idaho Falls, ID for Division of Systems Research, NRC, Washington, DC 20555. December 2001.
3) "Solving Reactor Water Clean-up System Anomalies Using RELAP5MOD3.3", Joseph S. Miller and Chris Brenan, 11th International Conference on Nuclear Engineering, ICONE11, Tokyo, JAPAN, ICONE11-36149, April 20-23, 2003.
4) "Calculation of Forces on Reactor Containment Fan Cooler Piping", Joseph S. Miller and Kevin Ramsden, 12th International Conference on Nuclear Engineering, ICONE12, Arlington, Virginia, ICONE12-49214, April 25-29, 2004.
5) "Validation of a Thermal Hydraulic Computer Code to Perform Two-Phase Multi-Component Force Calculations for Structural Evaluations", Joseph S. Miller and Kevin Ramsden, 13th International Conference on Nuclear Engineering, ICONE13, Beijing, China, ICONE13-50297, May 16-21, 2005.
6) I.E. Idel' Chik, "Handbook of Hydraulic Resistance, Coefficients of Local Resistance and of Friction", AEC-TR-6630, (1966).
7) "Flow of Fluids Through Valves, Fittings and Pipe", Technical Paper No. 410, CRANE, Twenty Fifth Printing 1991.
8) NAVCO PIPING DATALOG, National Valve and Manufacturing Company, Edition No. 10 (Rev. June 1, 1974) 1966.