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VALVE DYNAMIC MODEL PERFORMANCE SIMULATION FOR THE SALEM PWR PLANT (UNIT ONE)

REVISION 0

Prepared by

Arthur M. Hecht

Continuum Dynamics, Inc.
P.O. Box 3073
Princeton, New Jersey 08540

Prepared for

Public Service Electric and Gas Company
of New Jersey
80 Park Plaza
Newark, New Jersey 07101

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Approved by

Alan Bilanin

Alan J. Bilanin

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SUMMARY

A simulation of valve performance using the EPRI/Continuum Dynamics, Inc. valve dynamic model code is made for high quality steam flow for the New Jersey Public Service Electric and Gas Company's Salem PWR Plant, Unit One. The Crosby 6M6 safety valve is predicted to perform stably for upper adjusting ring settings of -190 and -250 notches, both for a lower ring setting of -18 notches. Due to present code limitations flow of loop seal water is neglected. However, code update to include discharge of loop seal water is near completion.

Using the Continuum Dynamics, Inc.'s quasi-steady back pressure computer program, a set of back pressure calculations for the Salem Plant, Unit One was carried out for all relief and safety valves open. The back pressure for the 1PR-3, 1PR-4 and 1PR-5 safety valves are predicted to be 635 psia, 688 psia and 616 psia, respectively, for steam initially saturated at 2500 psia and unit quality.

The effort was supported by the New Jersey Public Service Electric and Gas Company under Purchase Order No. E218736.

1. INTRODUCTION

At the request of Public Service Electric and Gas Company of New Jersey (PSE&G), Continuum Dynamics, Inc. (C.D.I.) has simulated the performance of the Salem PWR Plant, Unit One safety discharge valves using C.D.I.'s Valve Dynamic Model Code. This code was developed under the sponsorship of the Electric Power Research Institute as part of the EPRI SRV Test Program. The code is presently restricted to valve simulations for flow of high quality steam. Modifications to the code to include flow of subcooled water will be made in the near future, which will provide capability to analyze valve performance during loop seal clearing.

The Valve Dynamic Model Code is based on a control volume for quasi-steady steam flow through a spring loaded valve. The control volume analysis provides the net force acting on the valve disc. This force is utilized in a spring/mass/damper system equation to describe the valve stem motion given the reservoir pressure time history. The force contribution due to flow exiting the control volume is a function of the valve guide ring setting in terms of a predetermined geometric model. The steam flow is represented by an isentropic, ideal gas approximation. Coupling between the upstream piping acoustics and the valve motion is included in the model. Reference 1 contains a complete description of the valve model described briefly above.

In addition to the valve dynamic analysis, an evaluation of the Salem Unit One safety discharge piping pressure downstream of the safety valves is reported here. This back pressure was calculated for the plant-unique safety discharge line of this plant, including the effects of pipe fittings, shocks and area changes. The calculations were carried out using the C.D.I. Quasi-Steady Back Pressure Code, Reference 2, which is based on the assumption of steady-state adiabatic homogeneous equilibrium flow with friction. Frictional losses due to the presence of pipe fittings is accounted for by adding equivalent lengths of pipe.

The Salem Unit One safety discharge system utilizes Crosby 6M6 safety valves, a valve type tested during the CE/EPRI SRV Tests.

2. VALVE DYNAMIC MODEL SIMULATION

The important design features of a Crosby safety valve are shown in Figure 1, and a cross-section of the Crosby 6M6 internals is shown in Figure 2, approximately to full scale. The flow rates supplied to C.D.I. by PSE&G and which were used in the dynamic and back pressure analyses, are 470,000 lb/hr for the safety valves and 233,333 lb/hr for the relief valves. The adjusting ring settings used for this analysis were -190 and -250 notches for the upper guide ring and -18 notches for the lower ring. Two of the three Salem safety valve upper rings are set at the -190 value, with the third set at -250. Although the valve dynamic model code is presently being extended to include capability to treat the flow of subcooled water, the operational code is restricted to flow of high quality steam. The presence of loop seals is, therefore, neglected for the present.

The valve model was run including acoustic coupling between the valve and the upstream piping. The length of upstream piping used for the dynamic calculations consists of 16.2 feet of 6 inch diameter, schedule 160, derived using PSE&G Drawing Nos. 267PCL and 267PDL, Rev. 1, as supplied to C.D.I. by PSE&G. This length exists upstream of the 1PR-3 safety valve. The lengths upstream of the 1PR-4 and 1PR-5 valves are 14.5 and 13.9 feet, respectively. The longest existing length was, therefore, used for the performance simulation. Upstream piping for all three safety valves is 6 inch diameter.

The valve mass properties, spring rate, and geometric characteristics were assumed equal to the nominal values obtained either from the valve manufacturer or derived from the manufacturer's assembly drawings during code development. Table 1 presents a partial list of the important characteristics for the Crosby 6M6 valve.

The pressure time history used for the calculation was a linearly decreasing function of time, starting at 2575 psia and reaching 1700 psia in 4.5 seconds. For a set pressure of 2500 psia the valve, therefore, opens immediately and closes when the force balance on the valve disc yields a net force insufficient to keep the valve open against the spring force and the back pressure. (See Reference 1 for a detailed description of the valve model employed here.)

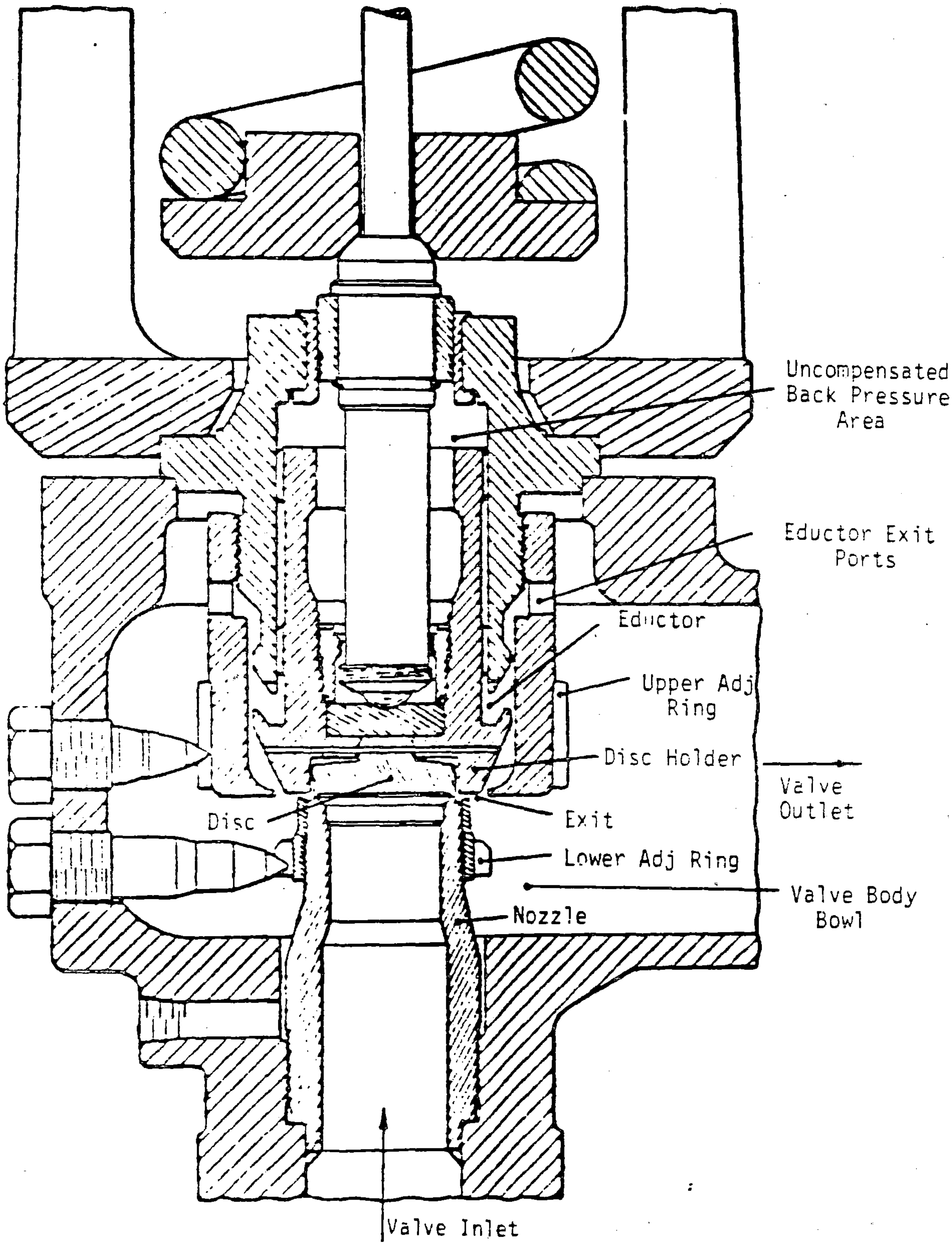

Figure 1. General design features of Crosby spring loaded safety valves

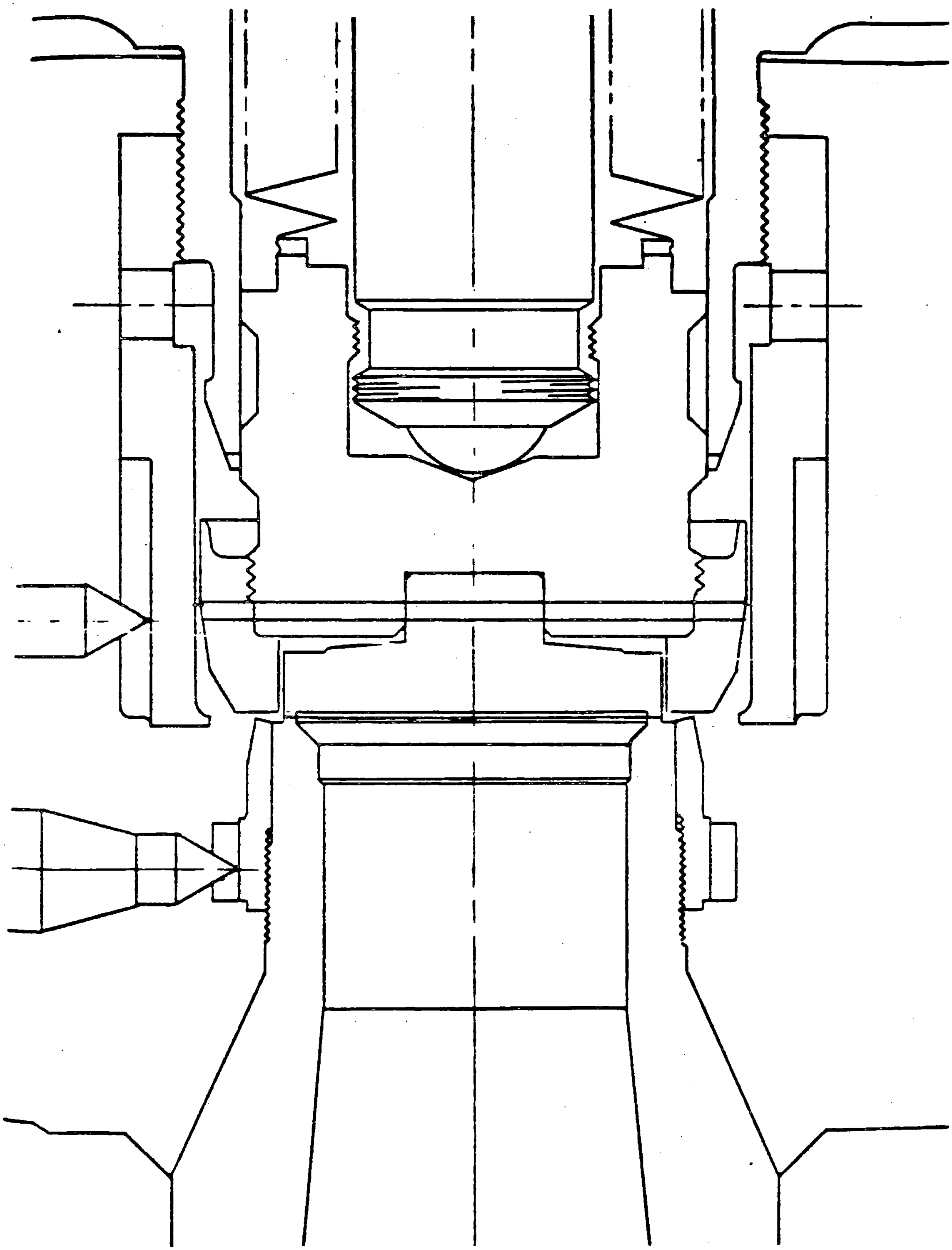

Figure 2. Details of the Crosby 6M6 safety valve

TABLE 1

Crosby 6M6 Characteristics and Geometric Parameters

Item	Units	Valve
Mass of moving parts	lbm	47.5
Spring mass	lbm	43.3
Maximum rated lift	in	0.538
Spring rate	lb/in	15070
Nozzle area	in^2	3.6
Exit area	in^2	3.4
Eductor area	in^2	0.4
Uncompensated back pressure area	in^2	5.54
Flange area	in^2	1.02

The valve stem position histories which result from the dynamic calculations are shown in Figures 3 to 5. Figure 3 shows the valve position for the -190 notch upper ring setting, including the effects of coupled upstream piping. Figures 4 and 5 are plots of valve position for an upper ring setting of -250 notches. The results shown in Figure 4 were obtained neglecting upstream piping, while those of Figure 5 include coupling effects.

The opening and closing characteristics predicted by the model are similar to the characteristics of Crosby 6M6 valves tested during the CE/EPRI SRV tests which opened on steam, e.g., test runs 903 and 1411. This code simulation indicates that the Crosby 6M6 valve operates stably on steam flow for the ring settings of the Salem Plant, Unit One. For the -190 and -18 notch settings on the upper and lower rings the code predicts a blowdown of 8.4%. For settings of -250 and -18 notches, the predicted blowdown in 8.6%.

It might be noted that since instability is more likely to occur as the length of upstream piping is increased, the present calculations using the longest upstream pipe length is conservative in this respect.

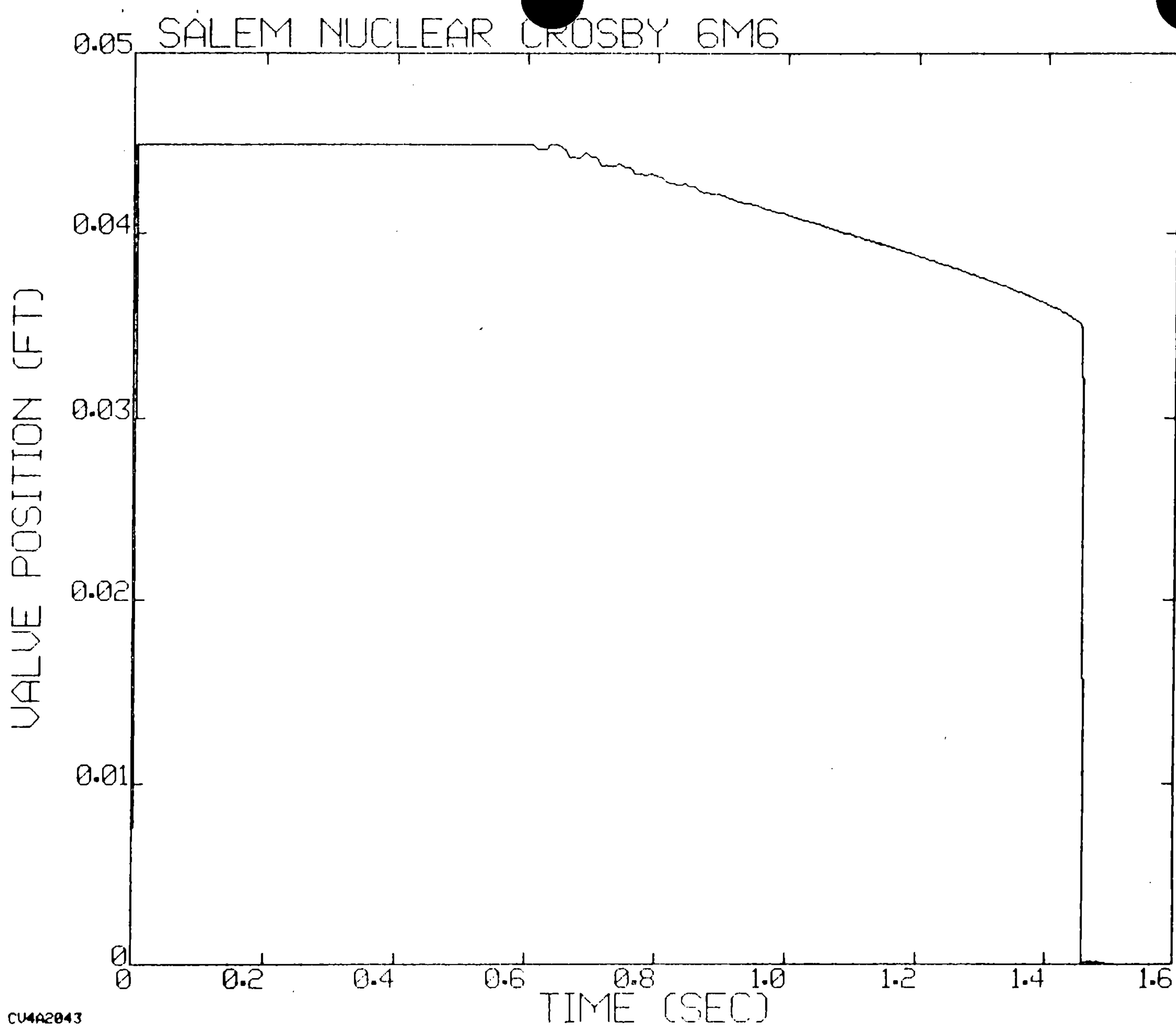

Figure 3. Valve stem position for the Salem Unit One Crosby 6M6 safety valve for notch settings of -190 on the upper adjusting ring and -18 on the lower, including the effects of upstream piping.

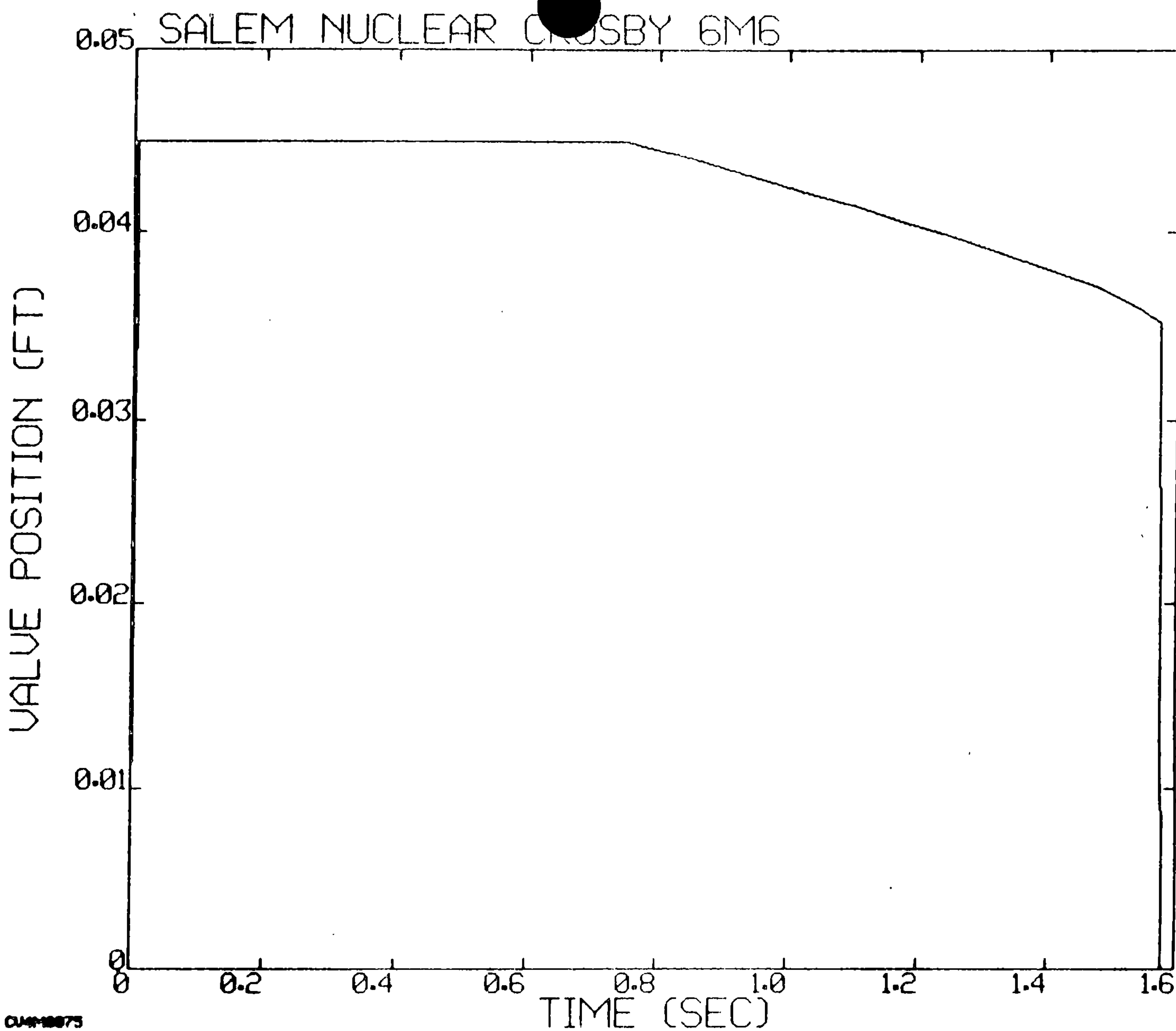

Figure 4. Valve stem position for the Salem Unit One Crosby 6M6 safety valve for notch settings of -250 on the upper adjusting ring and -18 on the lower, neglecting the effects of upstream piping.

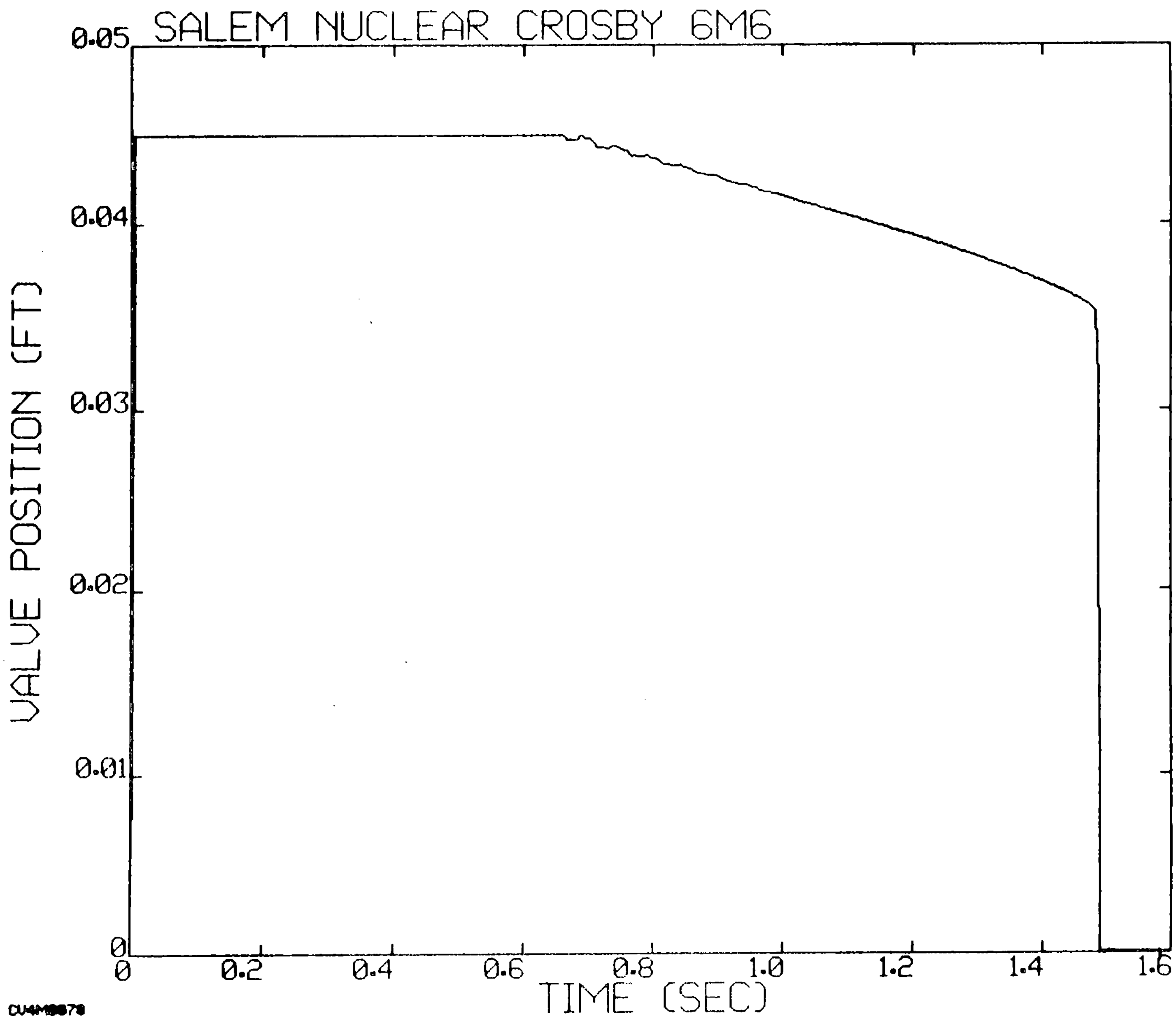

Figure 5. Valve stem position for the Salem Unit One Crosby 6M6 safety valve for notch settings of -250 on the upper adjusting ring and -18 on the lower, including the effects of upstream piping.

3. BACK PRESSURE ANALYSIS

The Salem Unit One Plant has three safety valves and two relief valves in the safety discharge lines. The back pressure calculations for the Salem Plant were made with all safety and all relief valves open. A schematic of the Salem Plant piping downstream of safety valve 1PR-4, which has the longest actual plus equivalent length piping for this plant, is shown in Figure 6. The pressure profile along this piping is given in Figure 7. The back pressure at the 1PR-4 valve exit is predicted to be 688 psia for a pressurizer pressure of 2500 psia and steam quality of one. Profiles for the 1PR-3 and 1PR-5 downstream piping are shown in Figures 8 and 9. The piping lengths in these last two figures continue only to their first branch point. The back pressure at the valve exit for these two valves is calculated to be 635 psia for the 1PR-3 valve and 616 psia for the 1PR-5 valve. Note that the back pressure calculated for one of the Salem Unit One safety valves and reported in Reference 2 was 478 psia for one safety valve open.

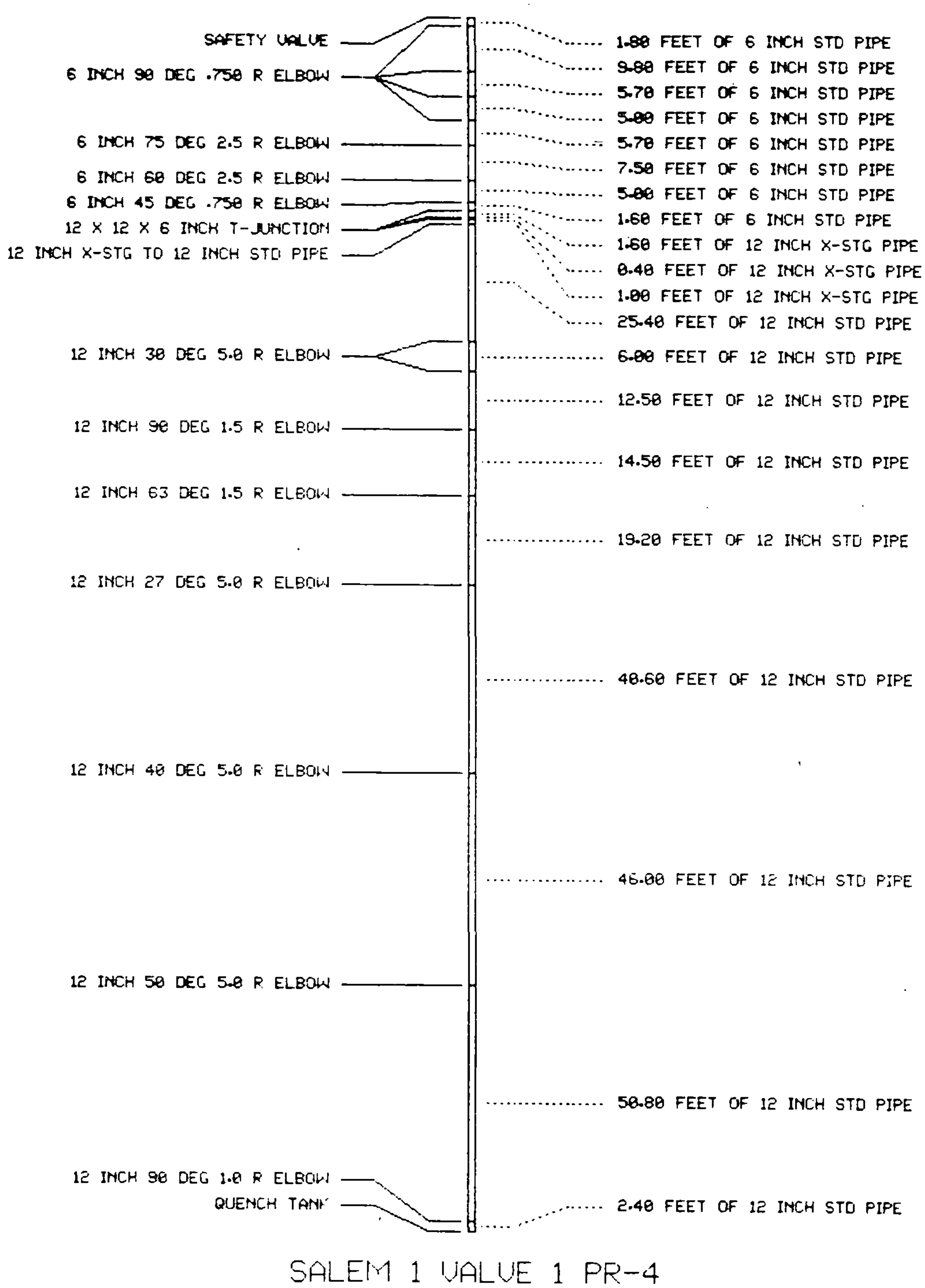

Figure 6. Salem Unit One discharge piping for safety valve 1PR-4

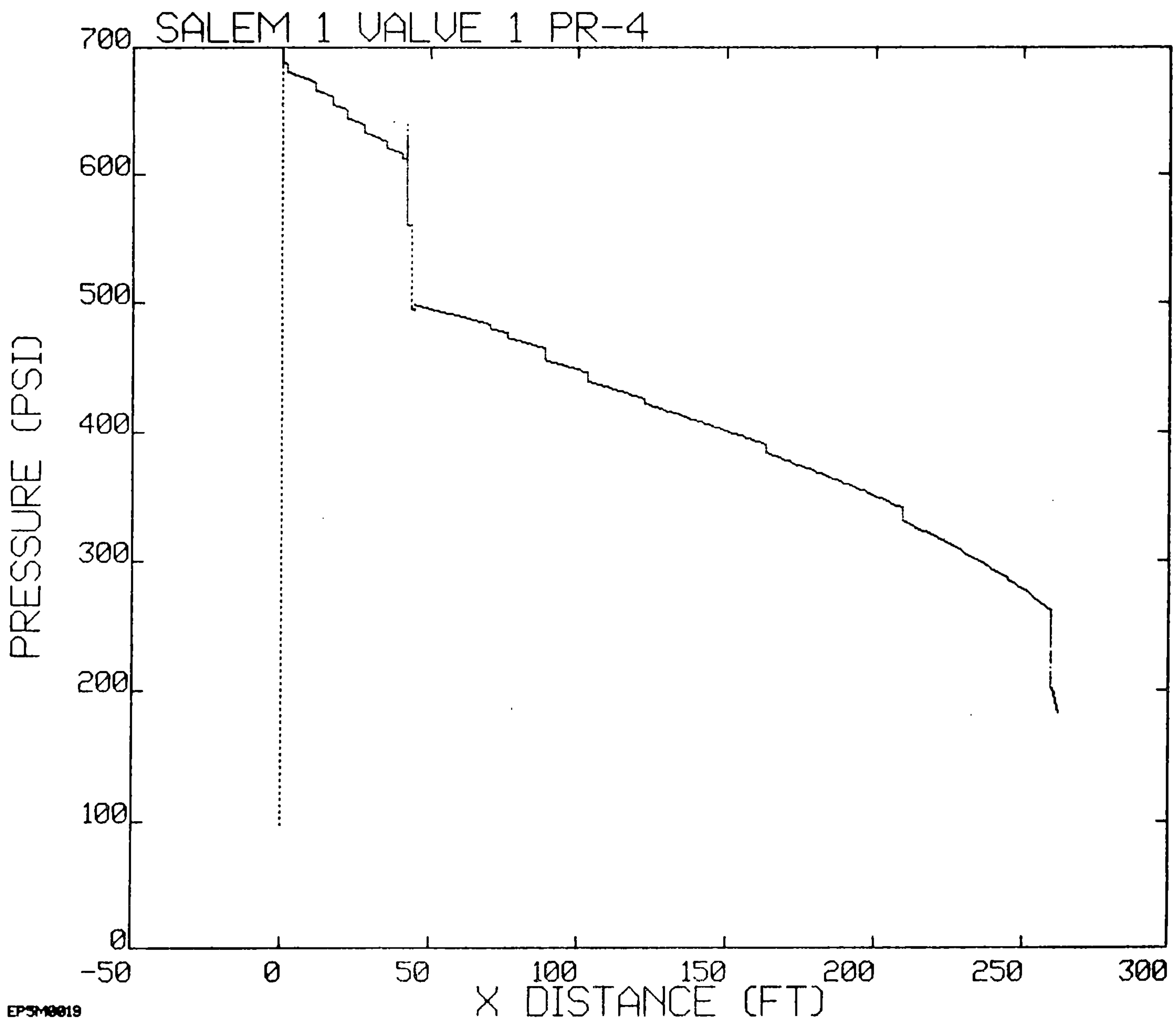

Figure 7. Downstream piping back pressure for the Salem Unit One 1PR-4 safety discharge line

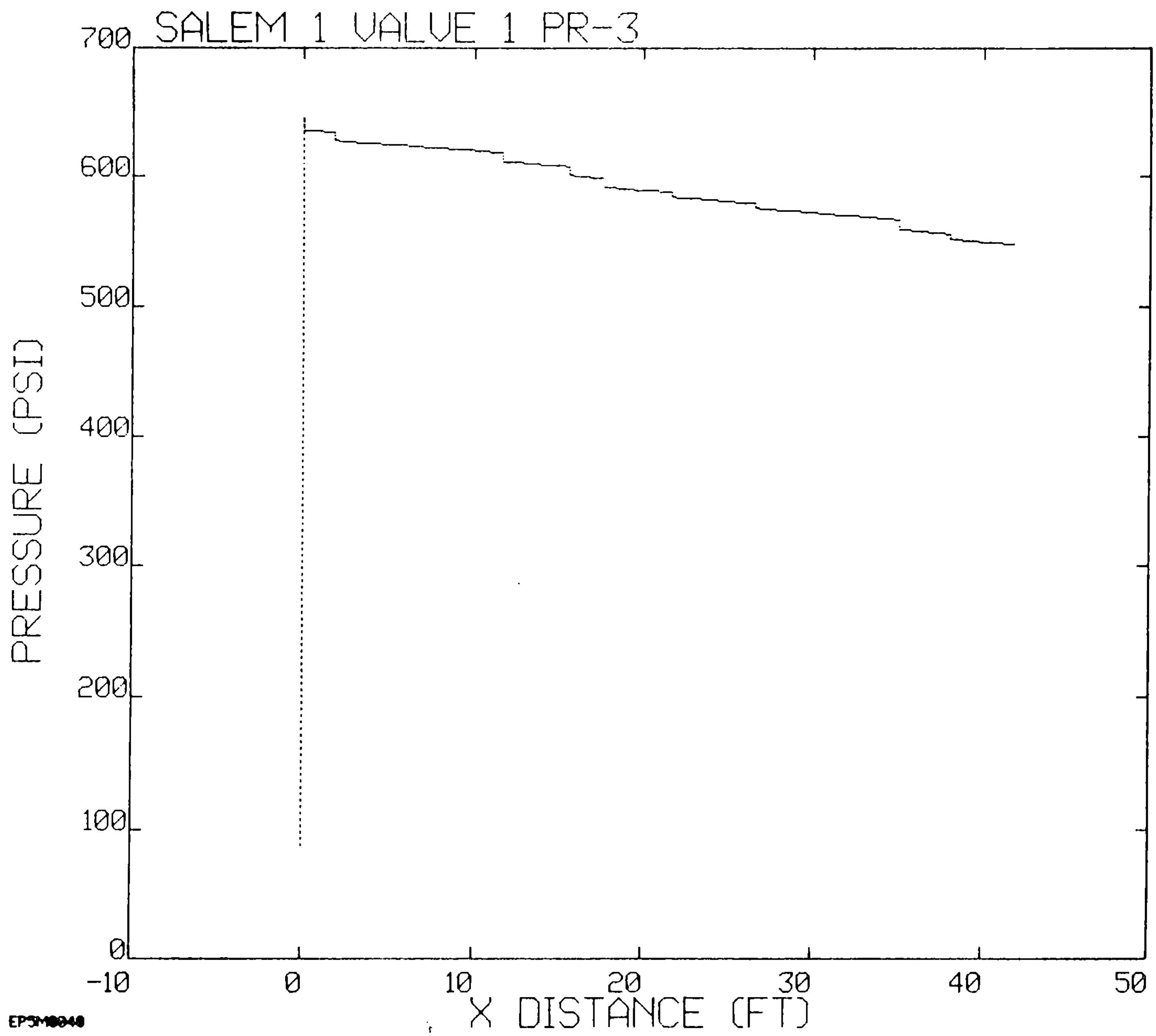

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Figure 8. Downstream piping back pressure for the Salem Unit One 1PR-3 safety discharge line

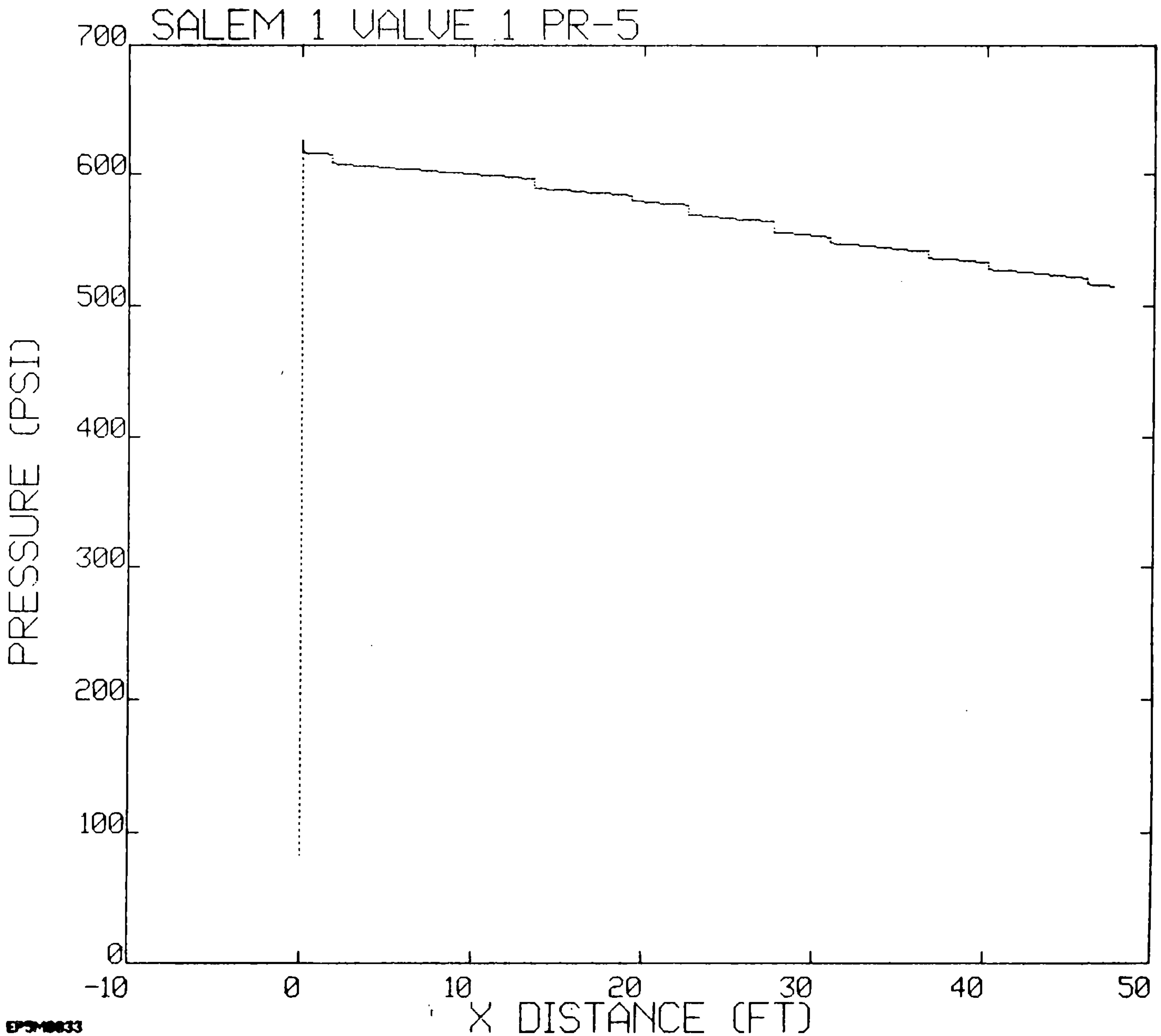

Figure 9. Downstream piping back pressure for the Salem Unit One 1PR-5 safety discharge line

4. CONCLUSIONS

A simulation of the Crosby 6M6 safety valve performance for the Salem Unit One Plant using the EPRI/C.D.I. Valve Dynamic Model Code has been made and indicates stable performance on discharge of high quality steam. Although loop seal clearing was neglected the simulation is felt to be representative of conditions for valve closure on steam flow. The ring settings of -190 notches and -18 notches for the upper and lower rings would, therefore, appear to lead to stable valve performance on steam for two of the valves, while the third is stable for settings of -250 and -18 notches for the upper and lower rings, respectively.

5. REFERENCES

1. Hecht, A.M., Teske, M.E. and A.J. Bilanin: "Coupled Valve Dynamic Model Technical Description," (Draft Report), Continuum Dynamics, Inc., July 1982. Prepared for participating utilities and the Electric Power Research Institute.

2. Hecht, A.M., Teske, M.E. and D.B. Bliss: "Quasi-Steady Back Pressure for Pressurized Water Reactor Safety and Relief Valves," Volumes I, II and II. Continuum Dynamics, Inc. Prepared for participating PWR Utilities and the Electric Power Research Institute.