Enclosure No. 1

B&W DOC. ID. 77-1150270-00

C.D.I. Report No. 83-4

SAFETY VALVE DYNAMIC ANALYSES

FOR DRESSER INDUSTRIES'

31739A and 31759A VALVES

Revision 1

Prepared by

Milton E. Teske

CONTINUUM DYNAMICS, INC.
P.O. Box 3073
PRINCETON, NEW JERSEY 08540

Prepared under Purchase Order No. 041982LU for

BABCOCK & WILCOX
P.O. Box 1260
LYNCHBURG, VIRGINIA 24505

Approved by

Alan J. Bilanin

Alan J. Bilanin

December 1983

ABSTRACT

Continuum Dynamics, Inc., has used the valve dynamic simulation code COUPLE, validated against the EPRI/C-E Safety Relief Valve Test Program data base, to determine the effect of valve geometry, adjustment ring positions and inlet and outlet pressure on valve performance under conditions of steam discharge in the Babcock & Wilcox nuclear power plants: Arkansas Nuclear One Unit 1; Crystal River Unit 3; Midland Units 1 and 2; Oconee Nuclear Station Units 1, 2 and 3; Rancho Seco and Three Mile Island Unit 1.

TABLE OF CONTENTS

REV. 1

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont'd)

LIST OF ILLUSTRATIONS (Cont'd)

LIST OF TABLES

DEFINITIONS

Actual mass flow rate:	rated mass flow rate divided by 0.9.
Back pressure:	the pressure at the discharge flange of the valve.
Maximum back pressure:	the maximum pressure at the discharge flange of the valve.
Maximum stem position:	the highest position obtainable by the valve stem.
Percent accumulation:	percent above set point pressure to which the pressurizer rises during a transient (e.g., 3% accumulation gives a pressurizer pressure of 2575 psig for a set point pressure of 2500 psig).
Percent blowdown:	a measure of the pressurizer pressure at which the valve closes (e.g., for the Dresser valve, blowdown is computed by computing (2515-p)/2500 where 2515 psig accounts for gauge set point pressure, p is the pressure in the pressurizer when the valve closes, and 2500 psig is the set point value. If the closing pressure were p = 2215 psig, the percent blowdown would be 12%).
Rated mass flow rate:	the steam mass flow rate through the valve when the valve stem is at rated lift.
Rated stem lift:	the stem position at which the nozzle area equals the inside seat area.
Stability:	stable valve behavior implies that the valve opens and closes without oscillations in the valve stem position.
Static lift position:	valve stem position at which the spring force on the valve disc equals the hydrodynamic force on the disc.
Uncompensated area:	the area behind the valve upon which the valve body bowl pressure acts.
Valve body bowl pressure:	the pressure in the valve body bowl.

1. INTRODUCTION

The EPRI/C-E Safety Relief Valve Test Program (Ref. 1) investigated the performance of Crosby and Dresser safety valves under a range of upstream piping, pressurizer conditions and valve middle ring settings. In an attempt to quantify the installation constraints for satisfactory valve operation, the Electric Power Research Institute sponsored the development of a spring-loaded safety valve dynamic model coupled to the unsteady motion in the upstream piping system, resulting in the COUPLE code (Ref. 2). The results of this code have been validated against applicable EPRI/C-E test data for both Crosby and Dresser valves, and the code has been shown (in Ref. 2) to reliably predict valve stem position, stability and percent blowdown across the range of tested steam pressurizer pressures, valve ring settings, back pressures and piping configurations. The valve model developed in Ref. 2 incorporates the major geometrical and physical valve features (including spring rate) to predict valve performance in response to changes in mass flow rate and internal pressure forces acting within the five tested valve types.

The objective of this study is to apply the validated COUPLE code to the specific geometrical and physical features of the Dresser valves present in six Babcock & Wilcox nuclear power plants, to understand the effect on valve performance of all relevant variables included in the valve model, and to provide a reliable plant-specific data base from which a selection of middle ring positions can be made. The six Babcock & Wilcox plants examined are: Arkansas Nuclear One Unit 1 (ANO-1); Crystal River Unit 3 (CR-3); Midland Units 1 and 2 (Midland-1 and Midland-2); Oconee Nuclear Station Units 1, 2 and 3 (Oconee-1, Oconee-2 and Oconee-3); Rancho Seco and Three Mile Island Unit 1 (TMI-1).

Section 2 of this report briefly summarizes the COUPLE valve dynamic model, and discusses the extension to two-phase flow (with steam tables) and an exit angle model improvement undertaken to more closely simulate the results found in the EPRI/C-E data base. Section 3 displays the valve geometric and mass characteristics for the Dresser Industries 31739A and

31759A valves in the Babcock & Wilcox plants, and develops parametric results. Section 4 summarizes the COUPLE code simulations that result in predicted valve performance for each of the six Babcock & Wilcox plants.

2. COUPLE VALVE DYNAMIC MODEL AND EXTENSIONS

The COUPLE valve dynamic model (described in detail in Ref. 2) computes the motion of the valve stem by solving for the hydrodynamic force on the valve disc using a control volume which includes (refer to Figure 2-1) the valve inlet area, valve seat area and valve exit area.

The upstream piping dynamics are computed assuming one-dimensional, compressible unsteady fluid flow. The flow rate through the valve is quasi-steady and determined from a critical flow model. The critical flow model serves as boundary conditions for the upstream piping model. Since the flow rate is proportional to the controlling critical area, which in turn is controlled by the valve stem position, the upstream piping dynamics are coupled to the dynamics of the valve internals themselves. Hence the name COUPLE.

The EPRI/C-E test series has shown that Dresser valve performance is sensitive to back pressure. The COUPLE code builds this sensitivity into the model by specifying an uncompensated area behind the valve disc where the valve body bowl pressure acts to close the valve. When the valve is closed, the body bowl pressure acting on the uncompensated area of the valve disc is atmospheric (assuming the downstream piping discharges to an unpressurized containment). As the valve opens the body bowl pressure builds up as the downstream piping is charged with steam. The effect of the body bowl pressure on valve performance is delayed by this charging (clearly seen in the EPRI/C-E data base, Ref. 1). This delay is built into the COUPLE code by approximating the steam charging time by an exponential function:

$$p(t) = p_c\left(1 - \exp(-t/t_c)\right) \qquad (2\text{-}1)$$

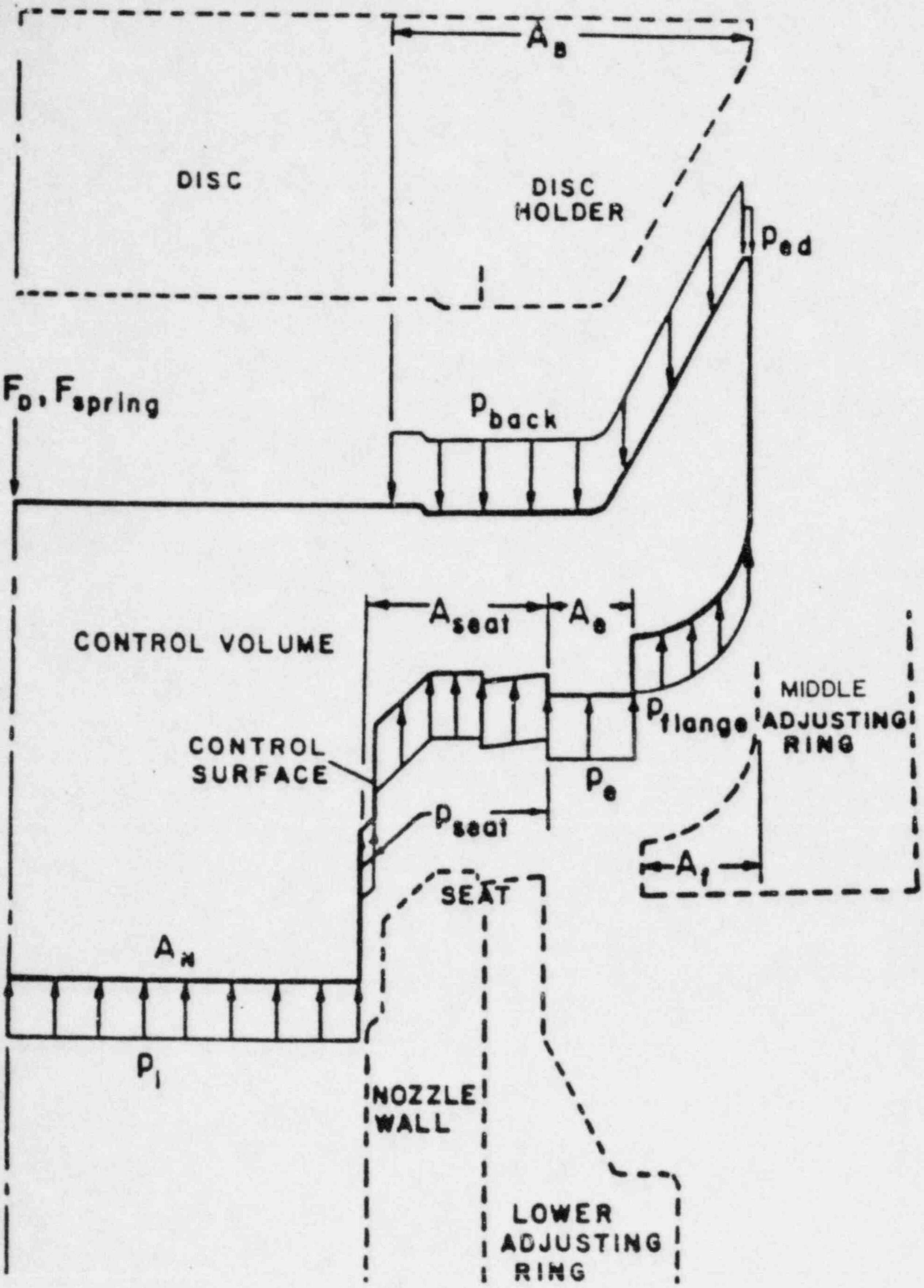


Figure 2-1. Identification of pressures acting on the flow and surface areas of the control volume

where the body bowl pressure $p(t)$ behind the valve approaches the steady state body bowl pressure, p_c, as time t exceeds the charging time t_c. In all calculations presented here $t_c = 10$ seconds and maximum accumulation is held for 30 seconds.

An examination of the EPRI/C-E data base indicates that the valve body bowl pressure is proportional to valve mass flow rate:

$$p_c = K\dot{m} \tag{2-2}$$

where $\dot{m}$ is the mass flow rate and K is the proportionality constant. A least-squares correlation of body bowl and downstream piping back pressures for all applicable EPRI/C-E Dresser valve data has demonstrated (in Ref. 2) that for steam discharge:

$$p_c = 0.884p_B + 0.176p_o \tag{2-3}$$

where p_B is the downstream pipe back pressure and p_o is the pressurizer pressure. With a specification of p_B and p_o, Eq. (2-3) gives the body bowl pressure. With the additional specification of maximum mass flow rate, Eq. (2-2) determines the proportionality constant K. This constant is part of the input to the COUPLE code. For mass flow rates less than maximum, Eq. (2-2) is solved to obtain the body bowl pressure acting on the uncompensated area of the valve disc.

The results presented in Ref. 2 were based on an application of the COUPLE code assuming steam to be an ideal isentropic gas and a two-phase flow extension where the mass and momentum conservation equations are supplemented by an energy equation, and parameterized steam tables (from Ref. 3) define the equation of state.

Initial computation using the two-phase flow model in the COUPLE code demonstrated a reduced sensitivity to the flow exit angle θ_e as a function of middle ring setting (see Figure 2-2 for a schematic). In the EPRI/C-E work θ_e was assumed to be the average of the angles formed by a tangent drawn along the lower ring (θ_A) and a tangent drawn along the stem position - middle ring (θ_B). A better model may be obtained by assuming that the flow separates off the lower ring. Consequently, θ_A does not influence the exit angle, and θ_e may be reasonably equated to θ_B. This redefinition of the Dresser valve data from the EPRI/C-E tests results in an improved best-fit of data that includes exit angle sensitivity to middle ring position and a reduced mean error in blowdown prediction of 1.68% (a COUPLE code prediction of 10% blowdown will be error-bounded by a blowdown between 8.32% and 11.68%). Figure 2-3 compares the COUPLE code prediction of percent blowdown versus middle ring setting against the EPRI/C-E data for the tested Dresser valves 31739A and 31709NA. Figure 2-4 compares the stem lift versus middle ring setting at 3% accumulation, while Figure 2-5 compares the mass flow rate versus middle ring setting, also at 3% accumulation. On average for this data base the COUPLE code overpredicts the stem lift by 2.4% and conservatively underpredicts mass flow rate by 13.9%.

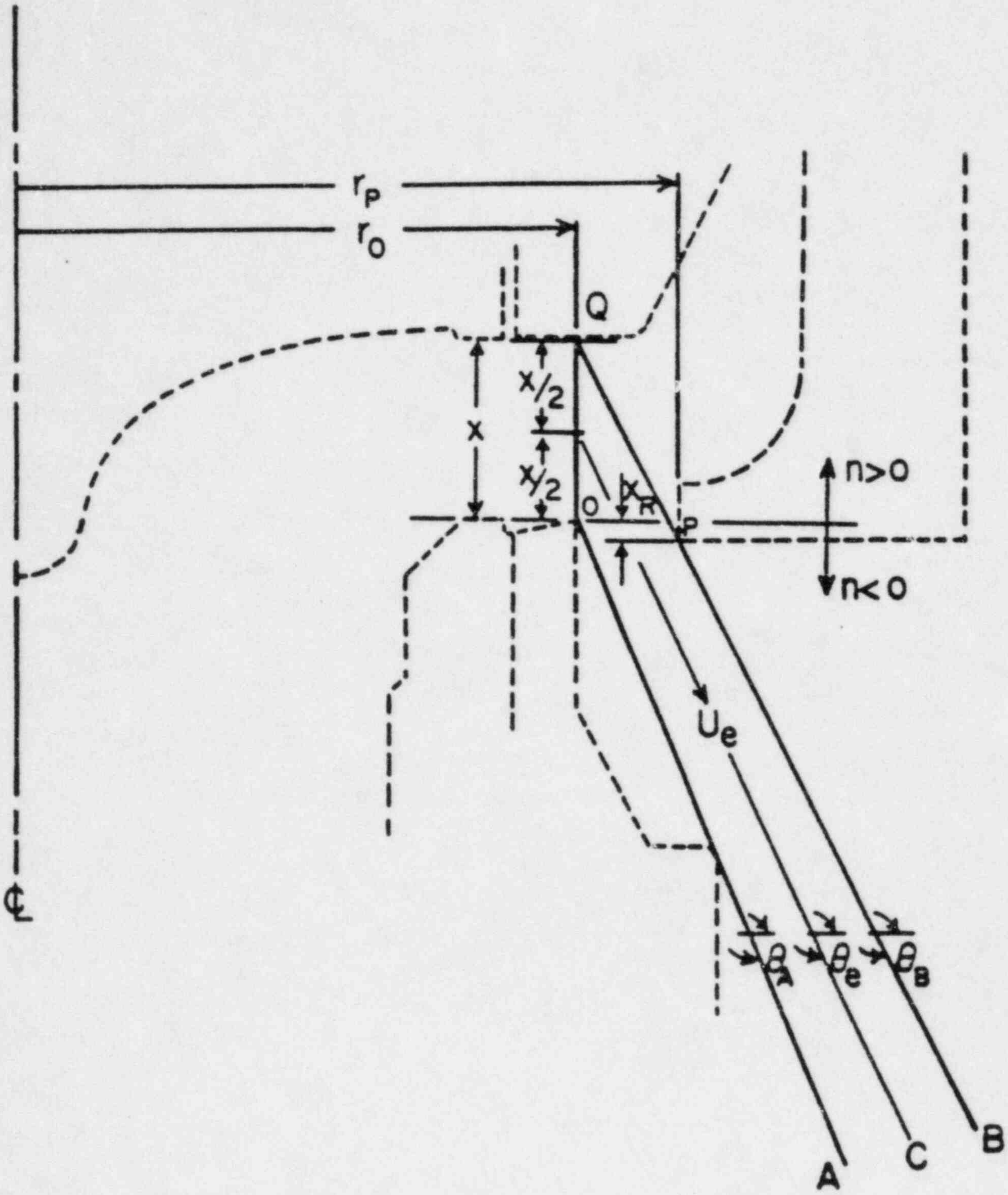


Figure 2-2. Method of geometric construction of exit angle θ_e

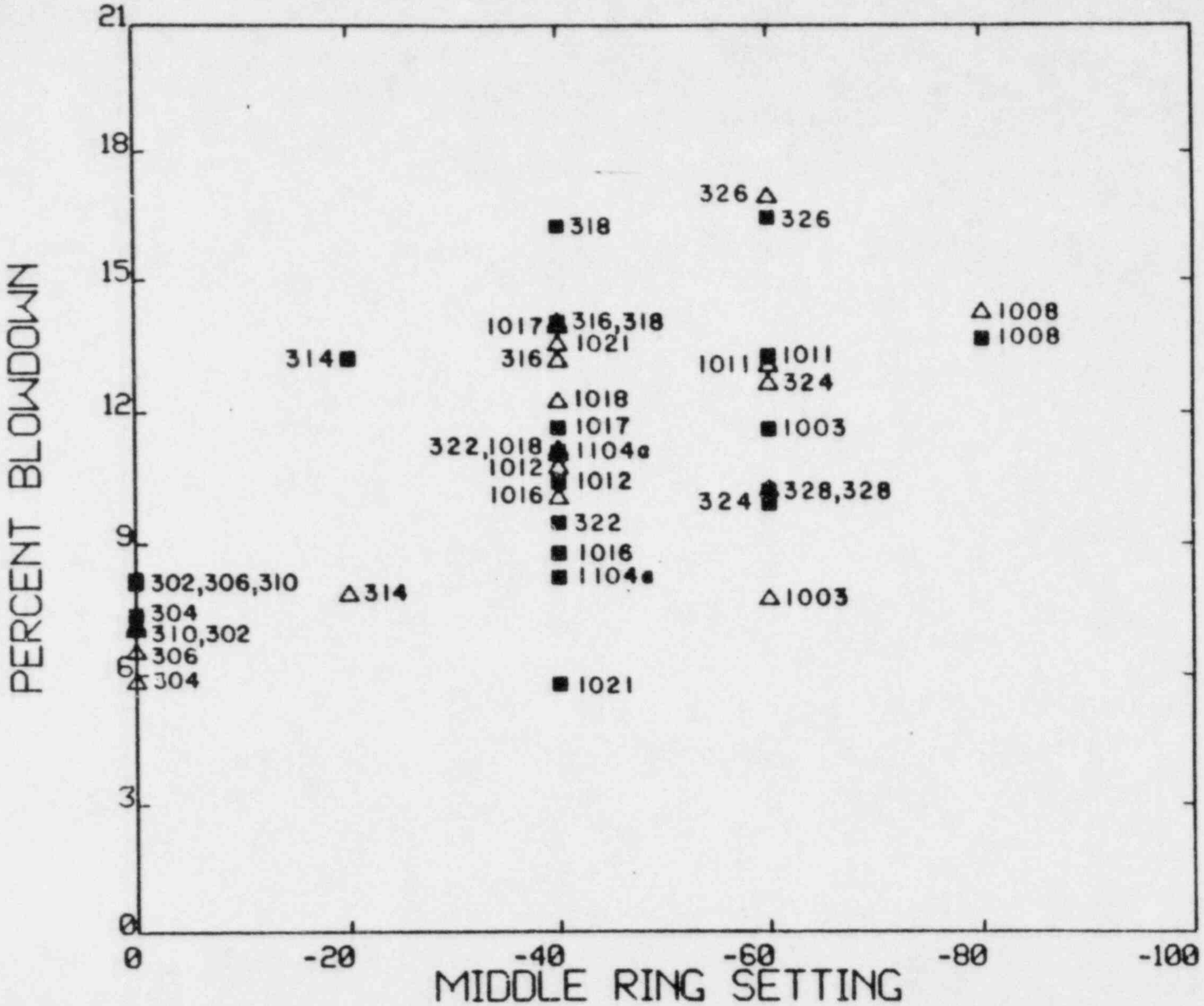


Figure 2-3a. Percent blowdown comparison for the Dresser 31739A valve between the EPRI/C-E data base (Δ) and the COUPLE code (■) - run numbers are consistent with Ref. 1

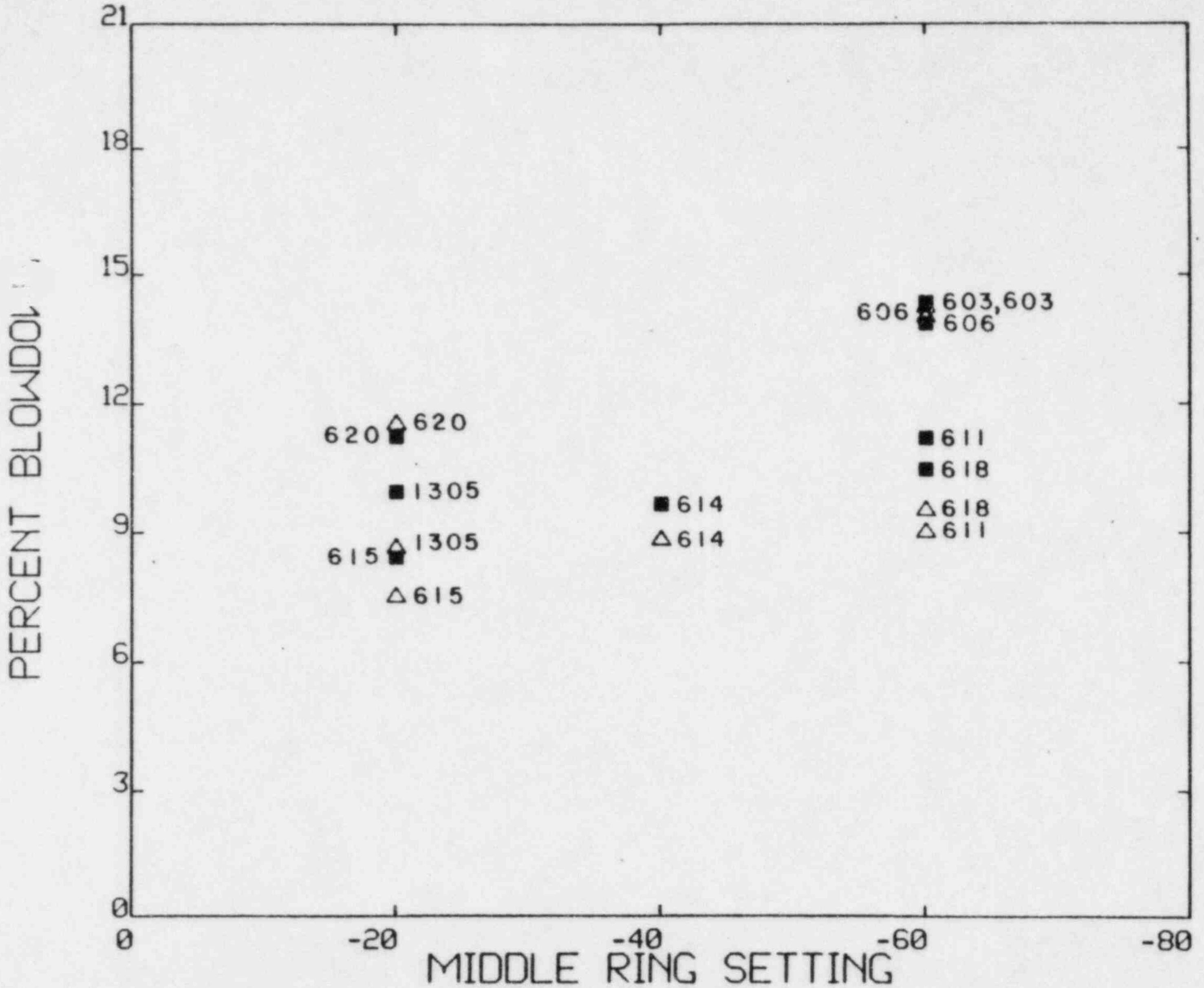


Figure 2-3b. Percent blowdown comparison for the Dresser 31709NA valve between the EPRI/C-E data base (Δ) and the COUPLE code (■) - run numbers are consistent with Ref. 1

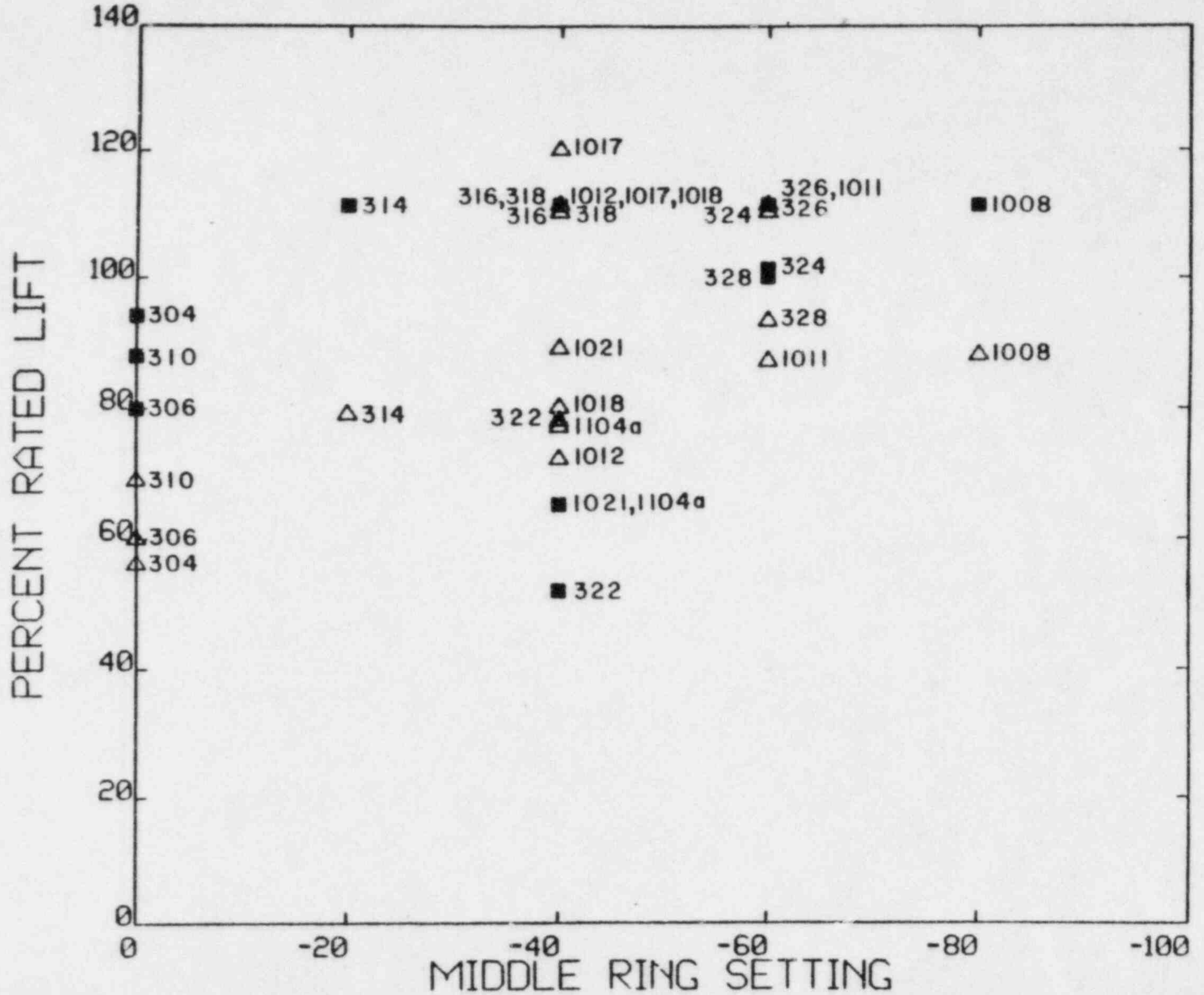


Figure 2-4a. Percent rated lift comparison for the Dresser 31739A valve between the EPRI/C-E data base (Δ) and the COUPLE code (■) - run numbers are consistent with Ref. 1

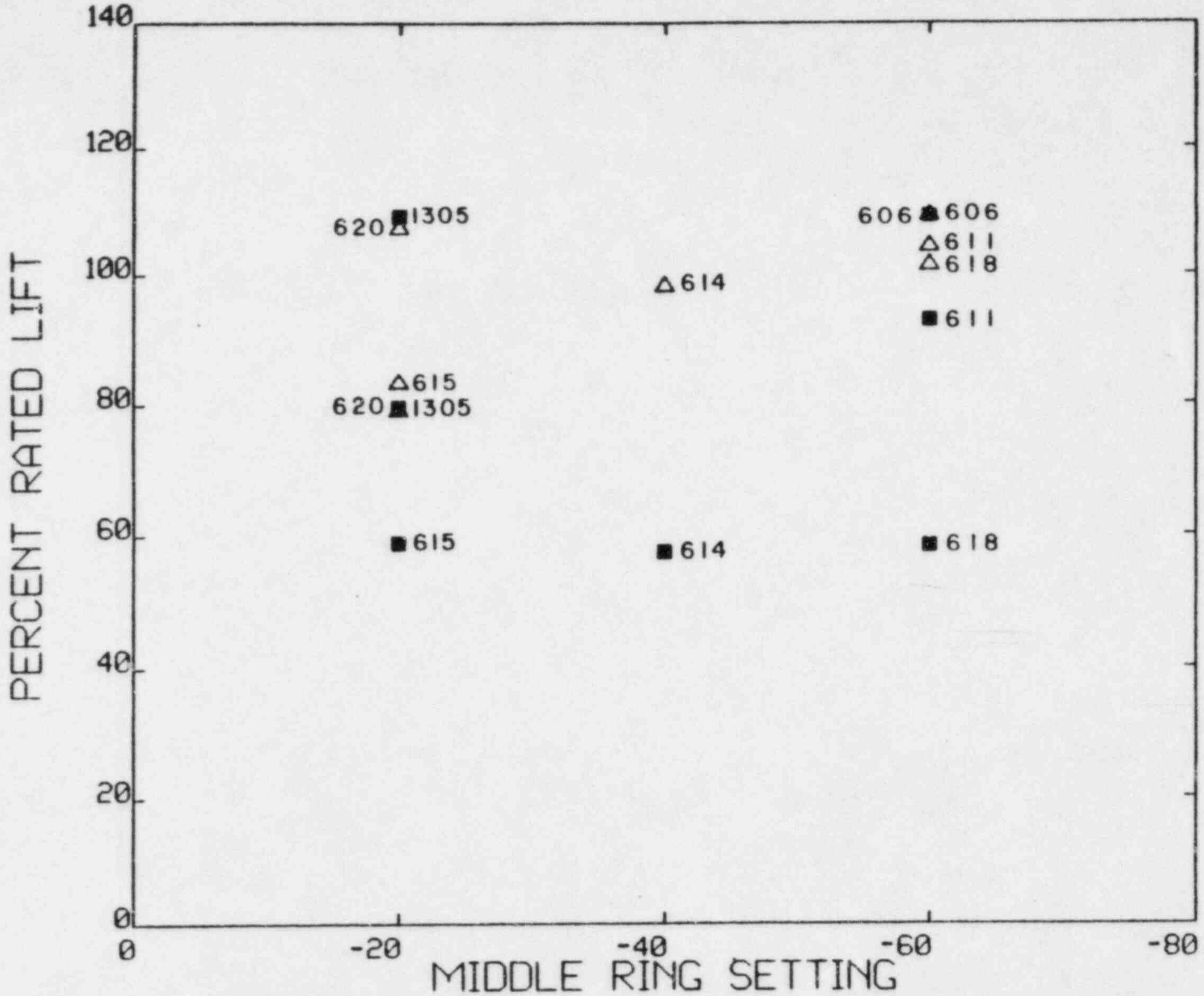


Figure 2-4b. Percent rated lift comparison for the Dresser 31709NA valve between the EPRI/C-E data base (Δ) and the COUPLE code (■) - run numbers are consistent with Ref. 1

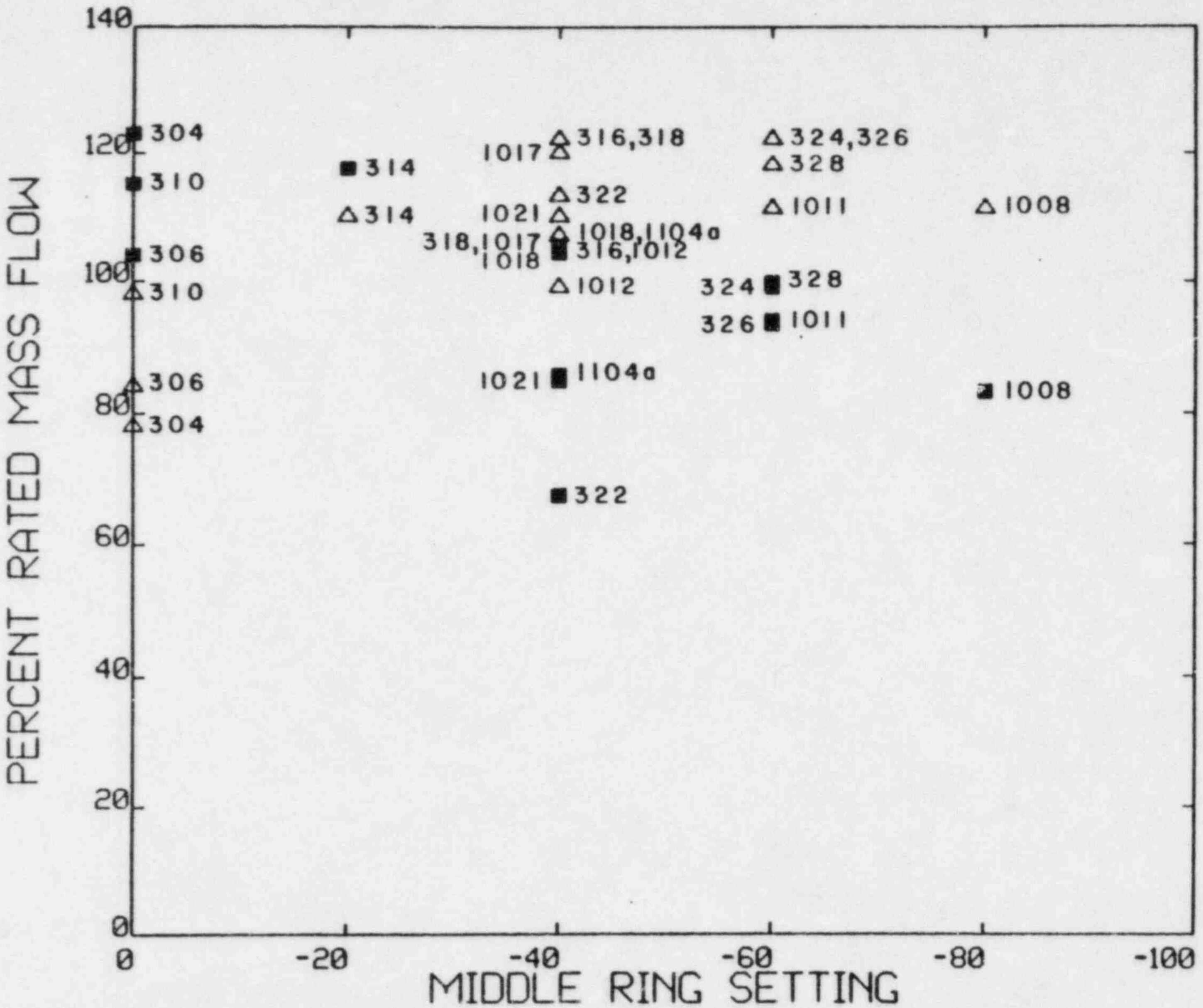


Figure 2-5a. Percent rated mass flow comparison for the Dresser 31739A valve between the EPRI/C-E data base (Δ) and the COUPLE code (■) - run numbers are consistent with Ref. 1

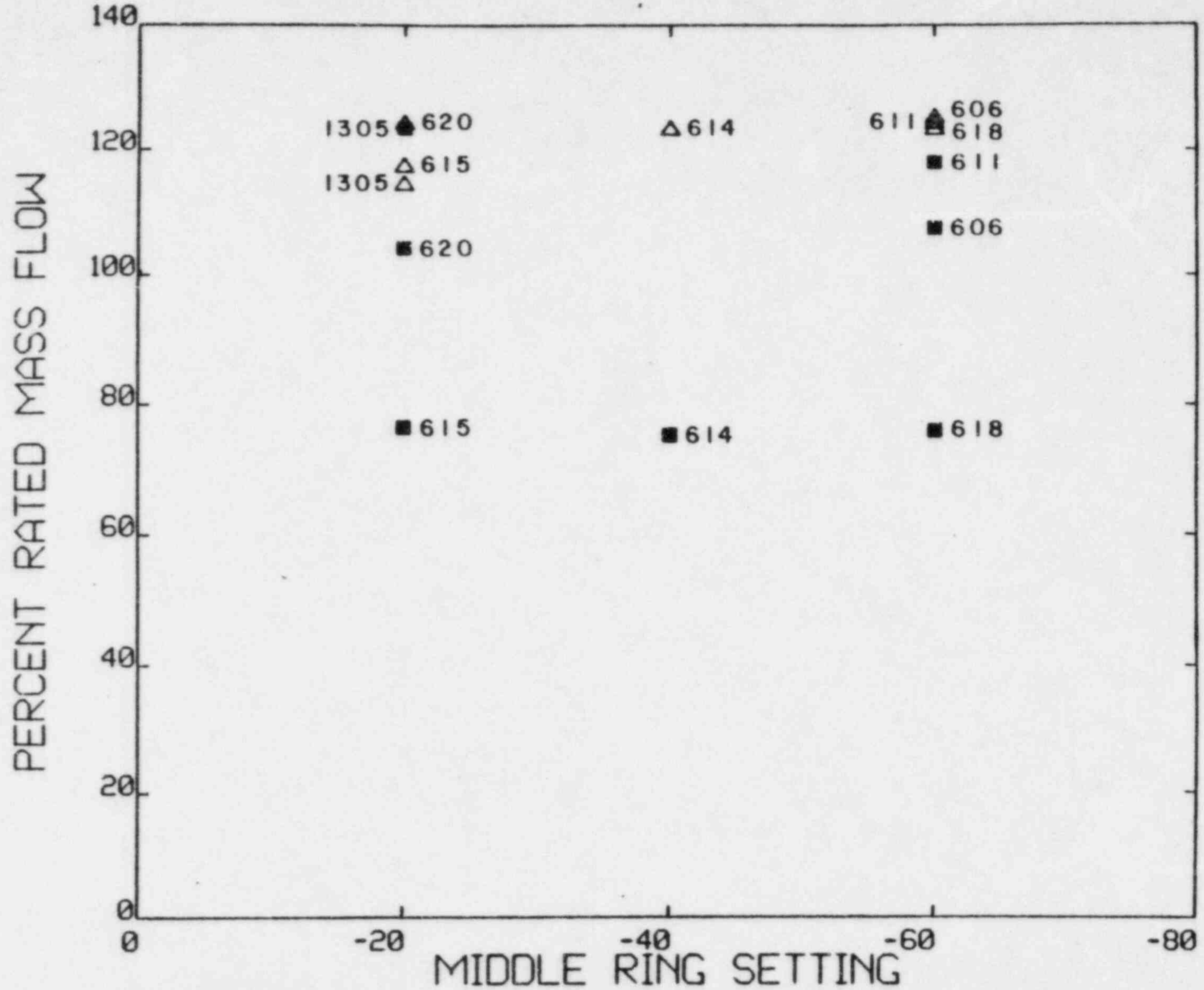


Figure 2-5b. Percent rated mass flow comparison for the Dresser 31709NA valve between the EPRI/C-E data base (Δ) and the COUPLE code (■) - run numbers are consistent with Ref. 1

3. VALVE CHARACTERISTICS AND PARAMETRIC RESULTS

To run the COUPLE code, the upstream piping characteristics, the geometric and inertial details of the valve internals, and the downstream back pressure effect acting on the uncompensated body bowl pressure area must be specified. These required code inputs are discussed here.

3.1 Upstream Piping Effect

The Dresser valves in the Babcock & Wilcox plants are typically installed on the pressurizer by a short inlet pipe of less than two feet (Figure 3-1). It is anticipated that a length this short will have little influence on valve operability, since the acoustic transit time is so small and the frictional pressure drop so low. To quantify this observation, a calculation was made for a 31739A valve with and without the presence of the pipe; frictional losses in the pipe were computed using steady state loss factors specified in Cranes, Ref. 4, and isentropic flow was assumed for computational efficiency. Figure 3-2 compares the stem position and mass flow as a function of time, where it may be seen that the valve behavior is nearly identical and the percent blowdown is comparable (12.4% for no pipe to 12.2% with pipe). In both cases the valve exhibits stem position as a function of time typical of that observed in the EPRI/C-E test program.

It is adequate therefore to use the COUPLE code for prediction without the presence of the pipe, significantly reducing computational expense without compromising the results.

3.2 Valve Geometric and Inertial Properties

Figure 3-3 represents a schematic of a typical Dresser valve, indicating the critical dimensions and information needed for the COUPLE code. Data supplied by Babcock & Wilcox for the two Dresser valves considered here are summarized in Table 3-1. The upper ring is not modeled in the COUPLE code, whereas the lower ring setting is prescribed at +8 notches (0.008 inches below

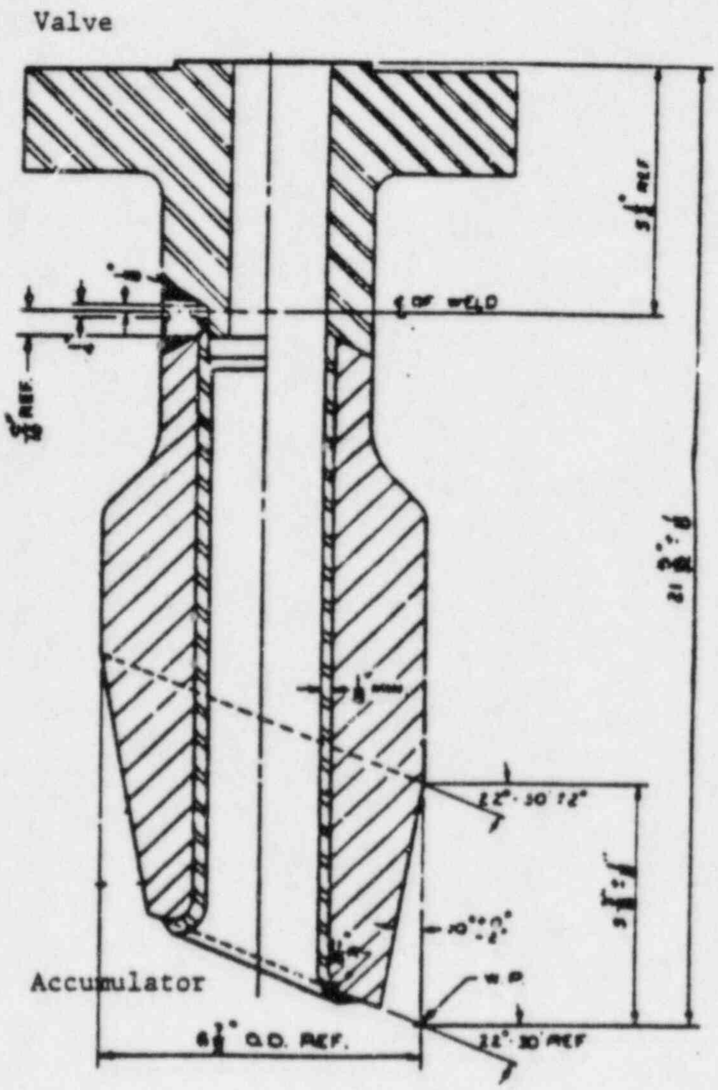


Figure 3-1. Typical inlet piping configuration - the left side of the centerline is indicative of the nozzle before final bore and should be ignored.

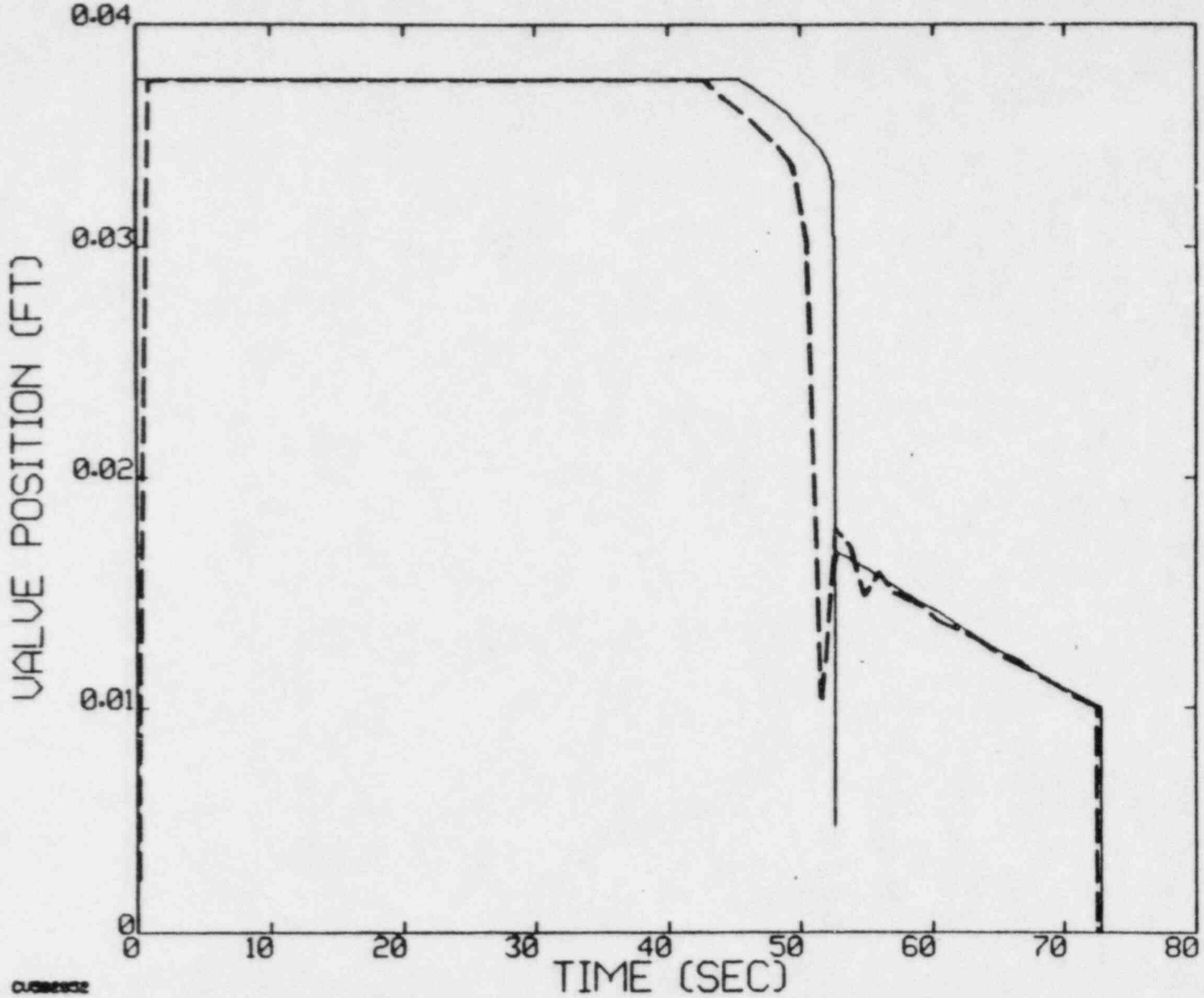


Figure 3-2a. Valve stem position with and without upstream piping for isentropic flow through a Dresser 31739A valve with 450 psig maximum back pressure at a lower ring setting of +8 notches and a middle ring setting of -40 notches; ——— no pipe; - - - pipe

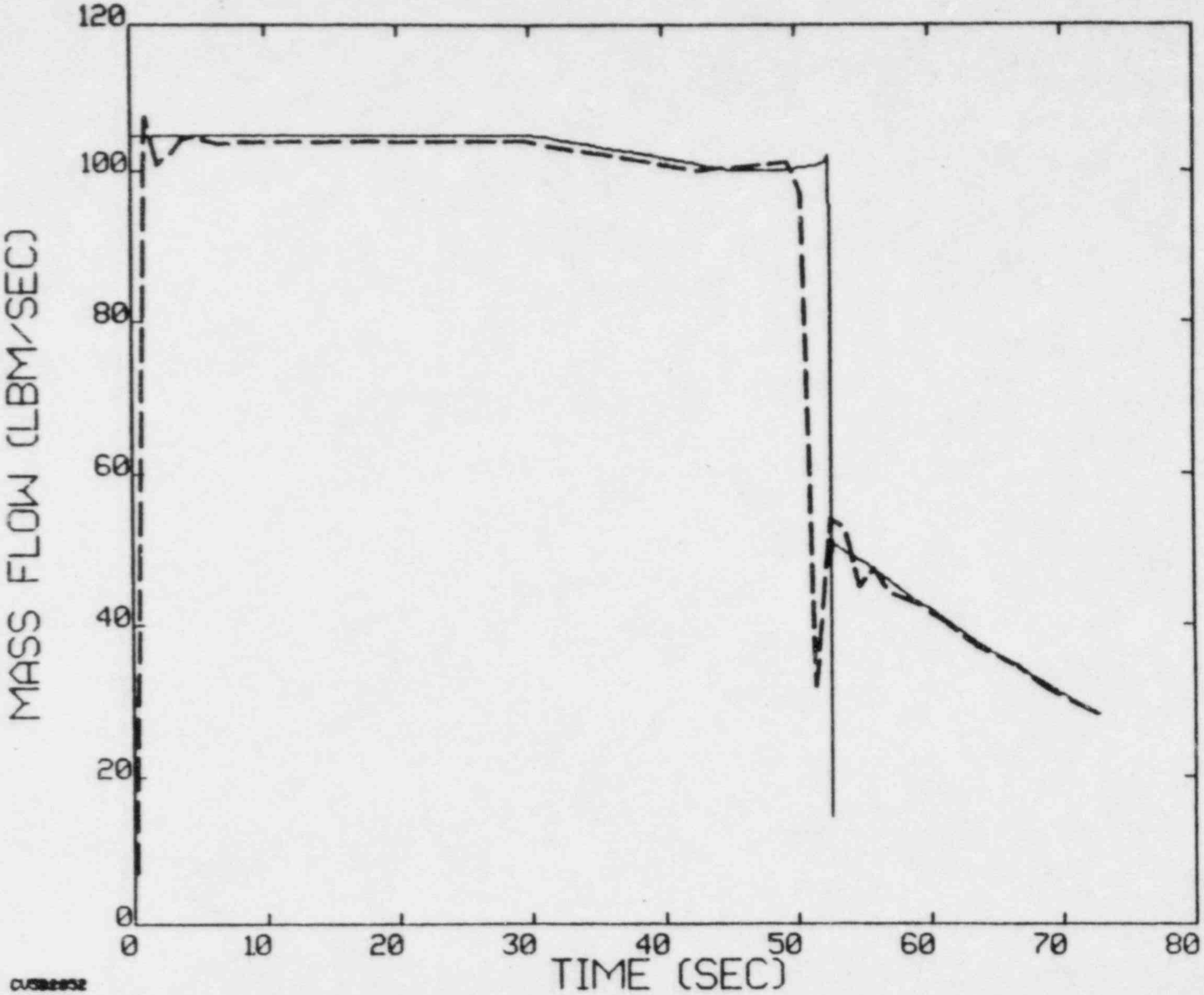
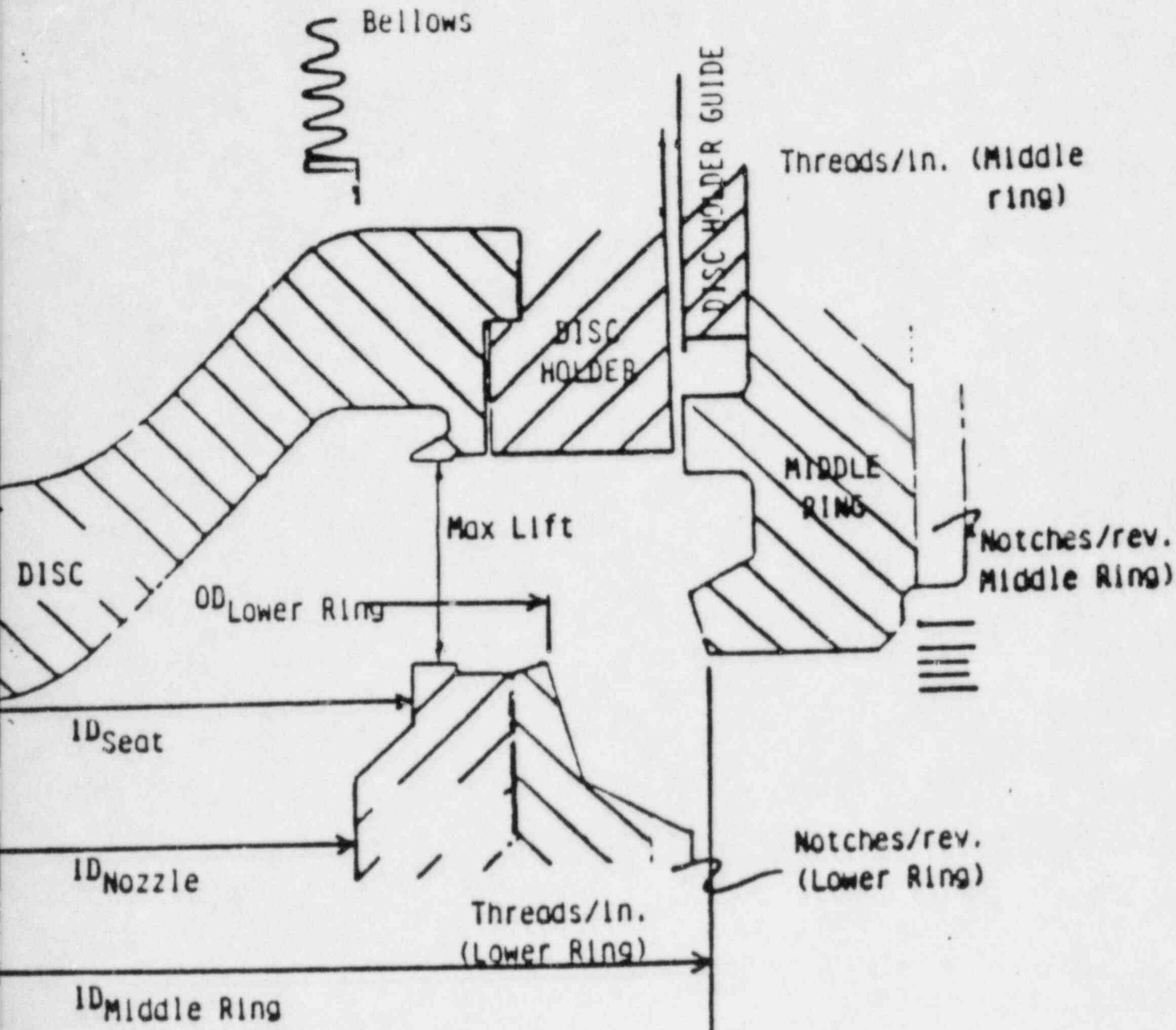


Figure 3-2b. Valve mass flow with and without upstream piping for isentropic flow through a Dresser 31739A valve with 450 psig maximum back pressure at a lower ring setting of +8 notches and a middle ring setting of -40 notches; ——— no pipe; - - - pipe



igure 3-3. Definition of geometric valve characteristics required as input to the COUPLE code

TABLE 3-1

Average Measured Valve Geometric and Inertial Characteristics

	Dresser 31739A*	Dresser 31759A**
ID nozzle	1.80 in	2.06 in
ID seat	2.110 in	2.424 in
OD lower ring	2.753 in	3.14 in
ID middle ring	3.516 in	4.06 in
Maximum lift	0.481 in	0.612 in
Mass of moving parts	53.1 lb	62.9 lb
Spring constant	13156 lb/in	16315 lb/in
Lower ring - threads/inch	16	16
notches/revolution	31	31
Middle ring - threads/inch	16	18
notches/revolution	41	37
Upper ring - threads/inch	14	16
notches/revolution	48	50
ASME rated mass flow at 2575 psig	297,845 lb/hr	391,000 lb/hr

* Values taken as average values of six Dresser 31739A valve measurements

** Values taken as values from ANO-1

the disc holder when the disc is in contact with the valve seat). This position was specified by Babcock & Wilcox in accordance with Dresser recommendations for providing ample clearance between the bottom ring and the disc holder when the valve is closed.

The valve characteristics given in Table 3-1 for the 31739A valve are average values from six 31739A valves. A sensitivity study was made around these average values for the parameters listed in Table 3-2 with 3% accumulation, a middle ring setting of -40 notches (0.061 in. below the valve seat) and zero upstream pipe length. All parameters were held in turn at their average values except one, which was set to its low, average and high values. Table 3-2 also gives the percentage variation of the parameter about its average value (spring rate values, for example, ranged from 12,288 lb/in., 93.4% of its average value, to 14,616 lb/in., 111.1% of its average value). Table 3-3 summarizes the valve blowdown sensitivity for maximum back pressure values of 200, 450 and 700 psig. In all cases in this report the maximum back pressure value will be achieved when the valve flows 110% rated ASME mass flow rate. This maximum back pressure value is used with the actual mass flow rate to determine the body bowl pressure proportionality constant using Eqs. (2-2) and (2-3). If the average blowdown were 10% with a maximum back pressure of 200 psig, Table 3-3 shows that spring rate variation will result in actual blowdown between 8.1% and 11.3% without correction for code uncertainties. An examination of Table 3-3 shows that spring rate is the most sensitive parameter in valve blowdown specification. Since the COUPLE code predictions of blowdown are error-bounded by ±1.68% in its modeling agreement with data, and peak tolerances for spring rate are -2.0% and +1.3%, the accuracy of the COUPLE code results for blowdown can be error-bounded by -3.7% and +3.0% (a blowdown prediction of 10% would be error-bounded by 6.3% and 13.0%). Sensitivity to the other valve parameters is much less, suggesting an error-bound on COUPLE code predictions of -1.9% and +2.1% in blowdown. REV. 1

Table 3-4 summarizes the valve lift sensitivity for maximum back pressure values of 200, 450 and 700 psig. For the 200 psig maximum back pressure case the valve always achieves full lift (106.9% of rated lift). None of the parametric variations affect the lift except the maximum lift variation, which gives results consistent with Table 3-2. For the 450 psig maximum back

TABLE 3-2

31739A Valve Sensitivity Parameters Including
Average Measured Values and Percent Variations

	Average Value*	Low Percent	High Percent
Nozzle inside diameter	1.800 in	-0.5	0.3
Seat inside diameter	2.110 in	-0.5	0.3
Lower ring outside diameter	2.753 in	-0.3	0.3
Middle ring inside diameter	3.516 in	-0.8	0.7
Back Pressure Area	5.12 sq in	-0.4	0.4
Valve weight	53.1 lb	-2.2	1.7
Maximum lift	0.481 in	-2.5	8.0
Spring rate	13,156 lb/in	-6.6	11.1

* Average taken as average value of six 31739A Dresser valve measurements

TABLE 3-3

31739A Valve Blowdown Sensitivity

	PERCENT BLOWDOWN DIFFERENCE FROM AVERAGE*					
Maximum back pressure (psig)	200		450		~~750~~ 700	
Tolerance	Low	High	Low	High	Low	High
Nozzle inside diameter	0.3	-0.1	0.4	-0.1	0.2	-0.2
Seat inside diameter	-0.1	0.1	-0.2	0.3	0.0	0.0
Lower ring outside diameter	0.0	0.1	0.0	0.2	-0.1	0.0
Middle ring inside diameter	0.0	0.2	-0.2	0.2	0.0	0.4
Back pressure area	0.2	0.1	0.0	-0.2	0.0	0.0
Valve weight	0.0	0.0	0.2	0.0	0.0	0.1
Maximum lift	0.0	0.2	-0.1	-0.1	0.0	0.0
Spring rate	1.3	-1.9	1.0	-1.8	1.1	-2.0

* Average taken as average value of six 31739A Dresser valve measurements. All calculations are made with a lower ring setting of +8 notches and a middle ring setting of -40 notches. REV.1

TABLE 3-4

31739A Valve Lift Sensitivity

	PERCENT RATED LIFT					
Maximum back pressure (psig)	200		450		700	
Tolerance	Low	High	Low	High	Low	High
Nozzle inside diameter	106.9	106.9	101.1	99.4	43.3	42.7
Seat inside diameter	106.9	106.9	100.0	100.0	42.6	43.1
Lower ring outside diameter	106.9	106.9	99.9	100.2	42.7	43.0
Middle ring inside diameter	106.9	106.9	96.4	103.0	42.4	43.3
Back pressure area	106.9	106.9	100.6	99.4	43.1	42.6
Valve weight	106.9	106.9	100.0	100.0	42.9	42.9
Maximum lift	104.3	115.5	100.0	100.0	42.9	42.9
Spring rate	106.9	106.9	106.9	50.7	46.3	38.2
Average values*	106.9		100.0		42.9	

* Average taken as average value of six 31739A Dresser valve measurements. All calculations are made with a lower ring setting of +8 notches and a middle ring setting of -40 notches. REV.1

pressure case the strongest variation is caused by the increase of 11.1% in spring rate. This change in spring rate reduces the valve lift from its average location at nearly full lift to a 50.7% rated lift position.

It is expected that the short inlet configuration in the Babcock & Wilcox plants will not modify the above sensitivity results. Thus, the Dresser 31739A valve will remain stable under all parametric variations considered here. In addition, a parametric variation of the Dresser 31759A valve for spring rate gives results indicating that inferences based on the 31739A sensitivity study are applicable to the 31759A valve as well.

3.3 Back Pressure Effect

Parametric results for the Dresser 31739A and 31759A valves were requested by Babcock & Wilcox for maximum back pressure values of 200, 450 and 700 psig. The effect of middle ring position is demonstrated in Figures 3-4 and 3-5, showing the predictions of the COUPLE code for percent blowdown, percent rated lift and percent rated mass flow, with zero upstream pipe length. Within this maximum back pressure range the valves exhibit stable blowdowns in the range of 3% to 18%. Percent rated lifts from 40% to 110% and percent rated ASME mass flow rates from 50% to 120% are also predicted.

Figures 3-4 and 3-5 must be approached with care. As discussed previously in Section 2, the maximum back pressure value is achieved only at 110% rated mass flow rate. Thus, along the 200 psig curve in Figures 3-4 and 3-5, the back pressure is 200 psig because the valve is passing 110% rated mass flow rate. Conversely, the back pressure along the maximum back pressure curves of 450 and 700 psig will be less than 450 and 700 psig, respectively, because the mass flow rate is less than 110% rated. The maximum back pressure, the pressurizer pressure and the actual ASME mass flow rate determine the body bowl pressure proportionality constant entered into the COUPLE code through Eqs. (2-2) and (2-3). Figures 3-4 and 3-5 imply, for example, that a 700 psig back pressure value will never permit rated lift or mass flow rate for the middle ring positions examined here. Instead, the valve will rest near 40% rated lift and 50% rated mass flow rate, with an actual back pressure value closer to 350 psig.

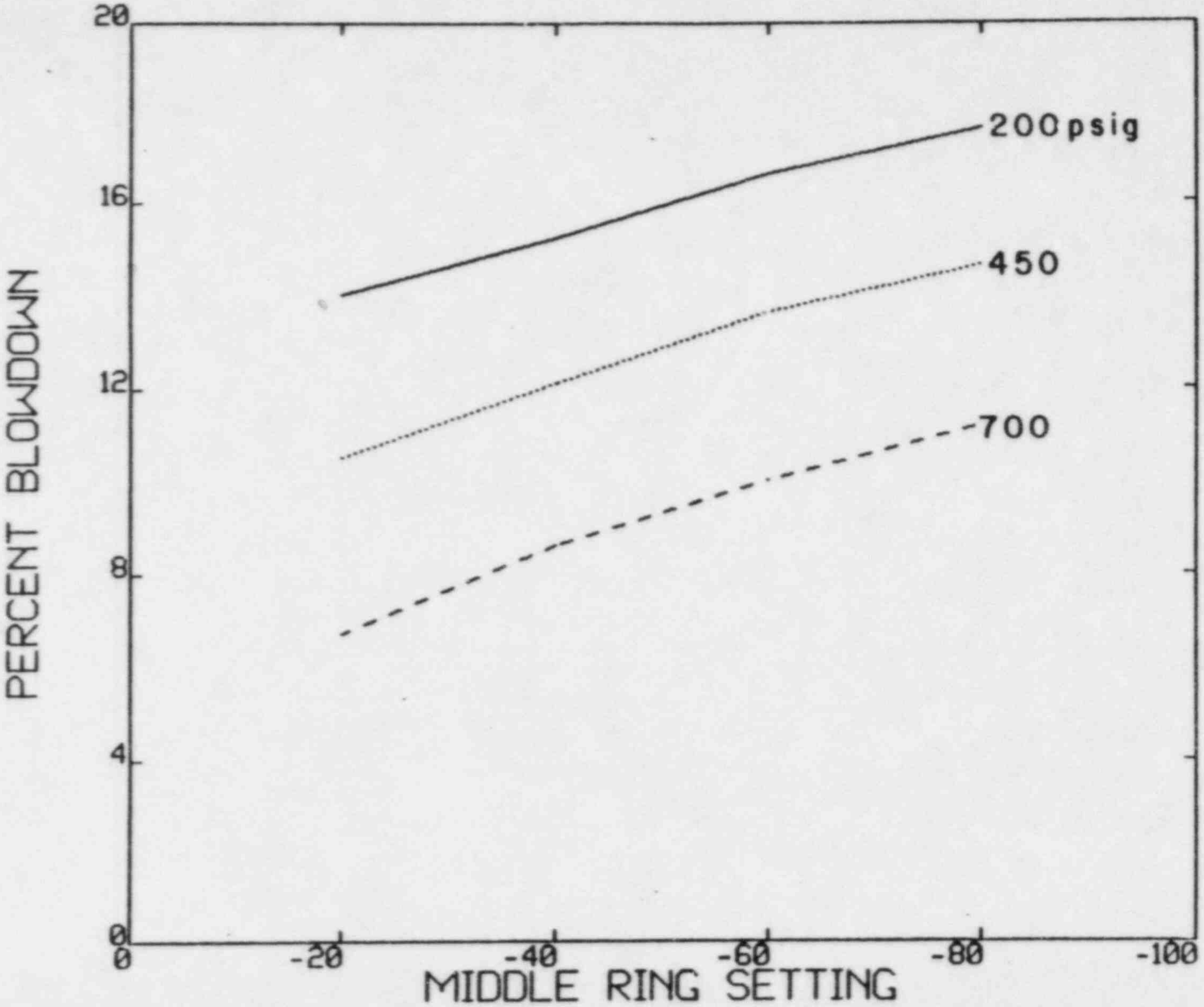


Figure 3-4a. Blowdown as a function of middle ring position and maximum back pressure for the Dresser 31739A - lower ring setting is +8 notches

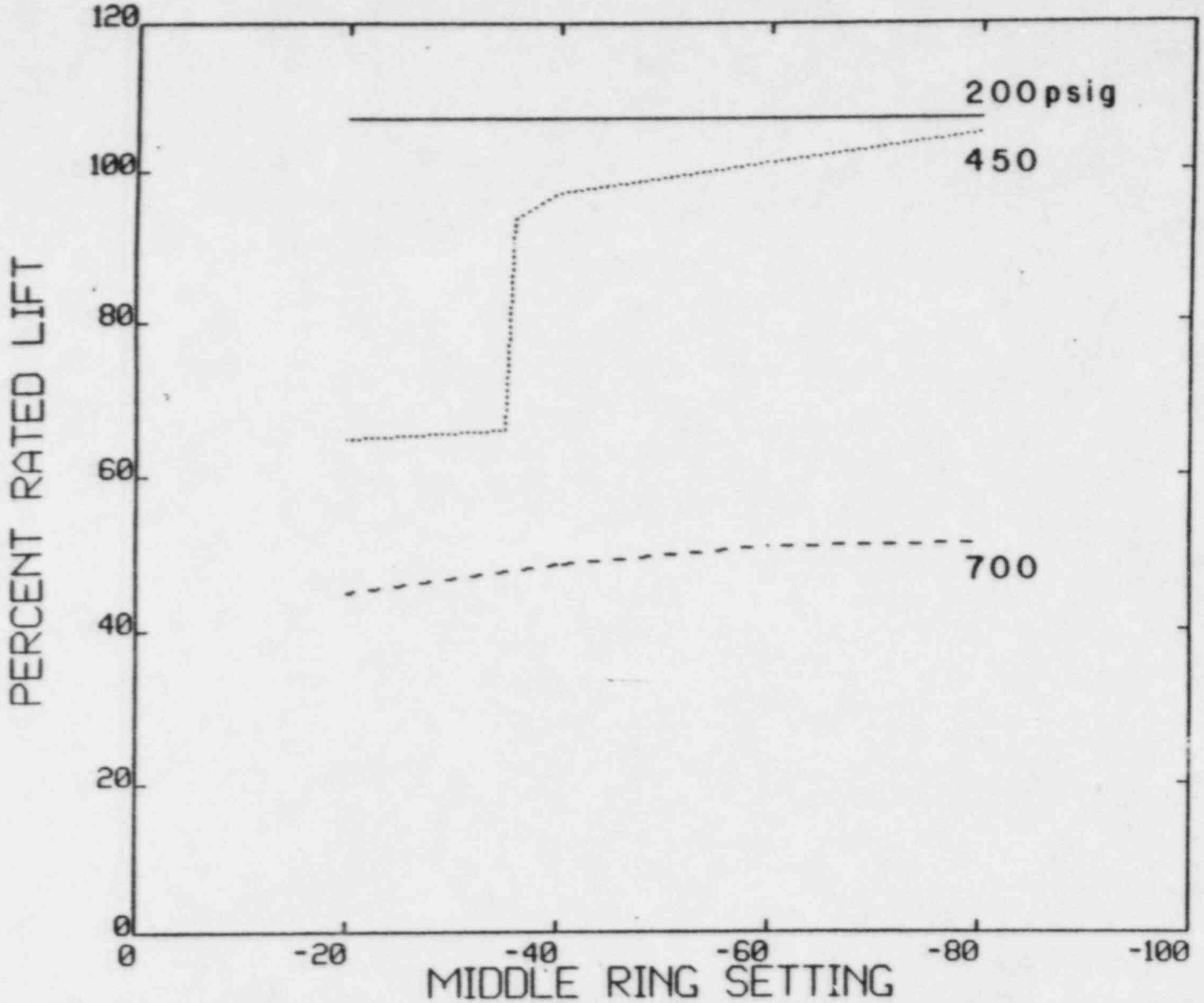


Figure 3-4b. Stem lift as a function of middle ring position and maximum back pressure for the Dresser 31739A - lower ring setting is +8 notches

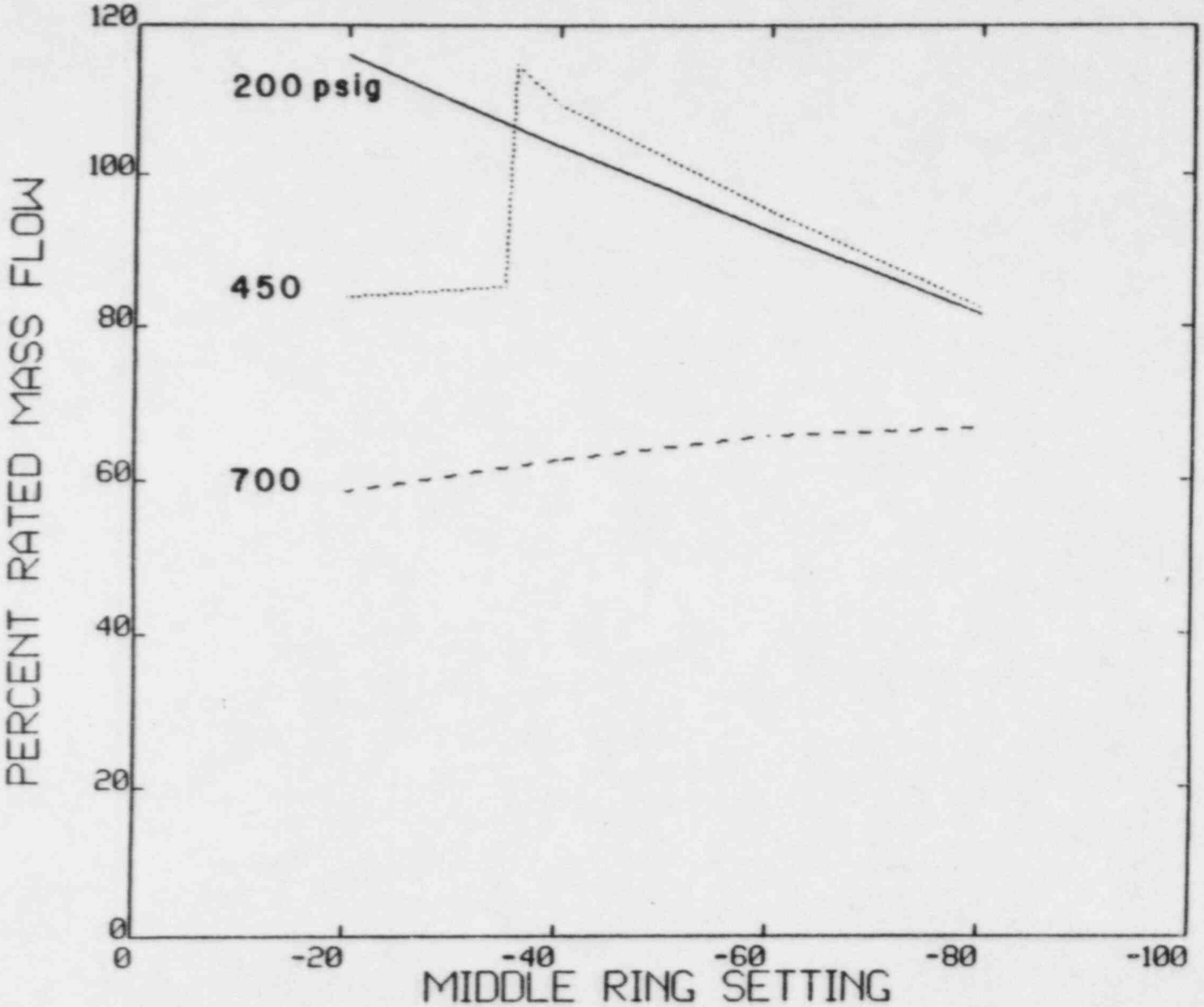


Figure 3-4c. Mass flow as a function of middle ring position and maximum back pressure for the Dresser 31739A - lower ring setting is +8 notches

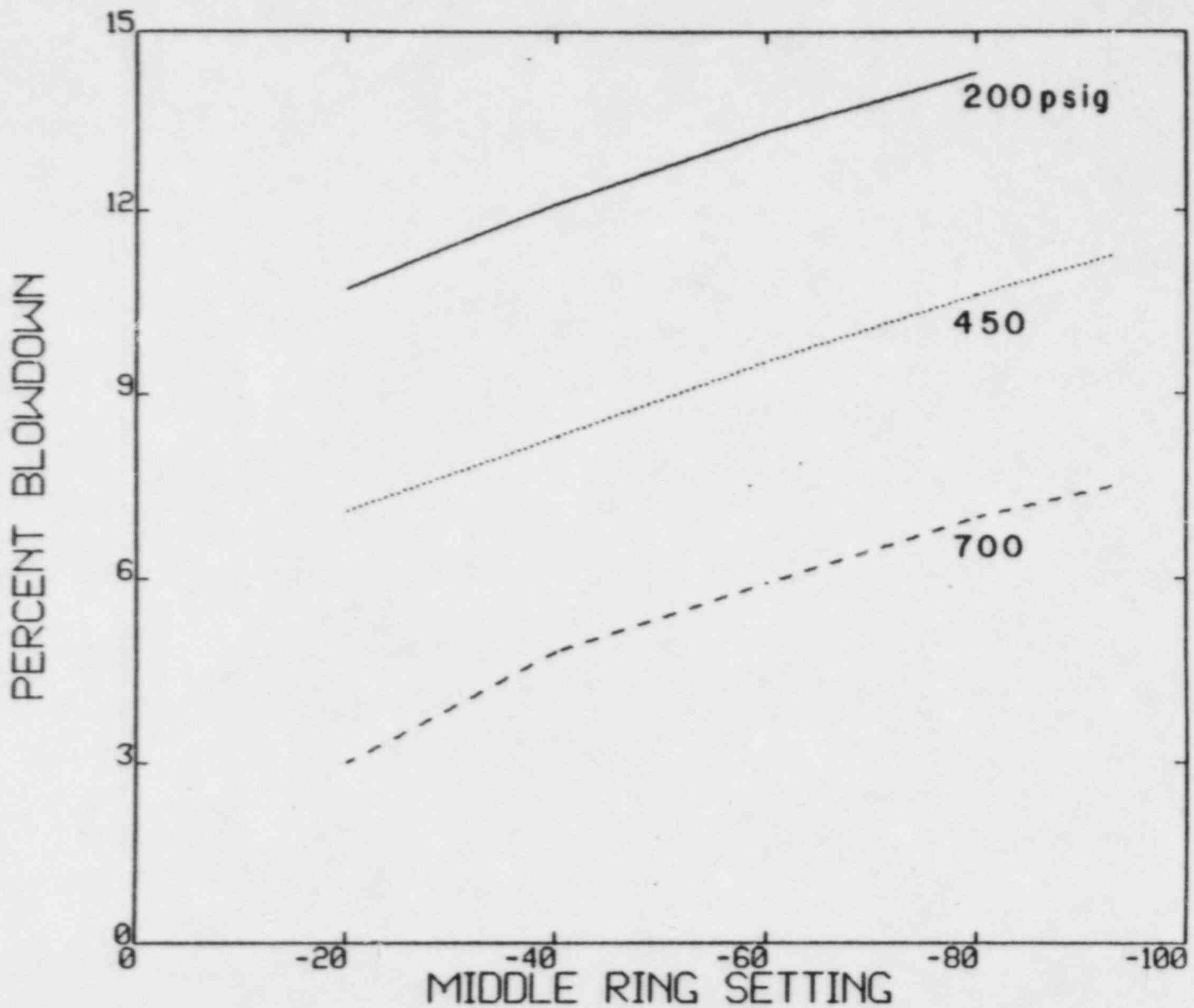


Figure 3-5a. Blowdown as a function of middle ring position and maximum back pressure for the Dresser 31759A - lower ring setting is +8 notches

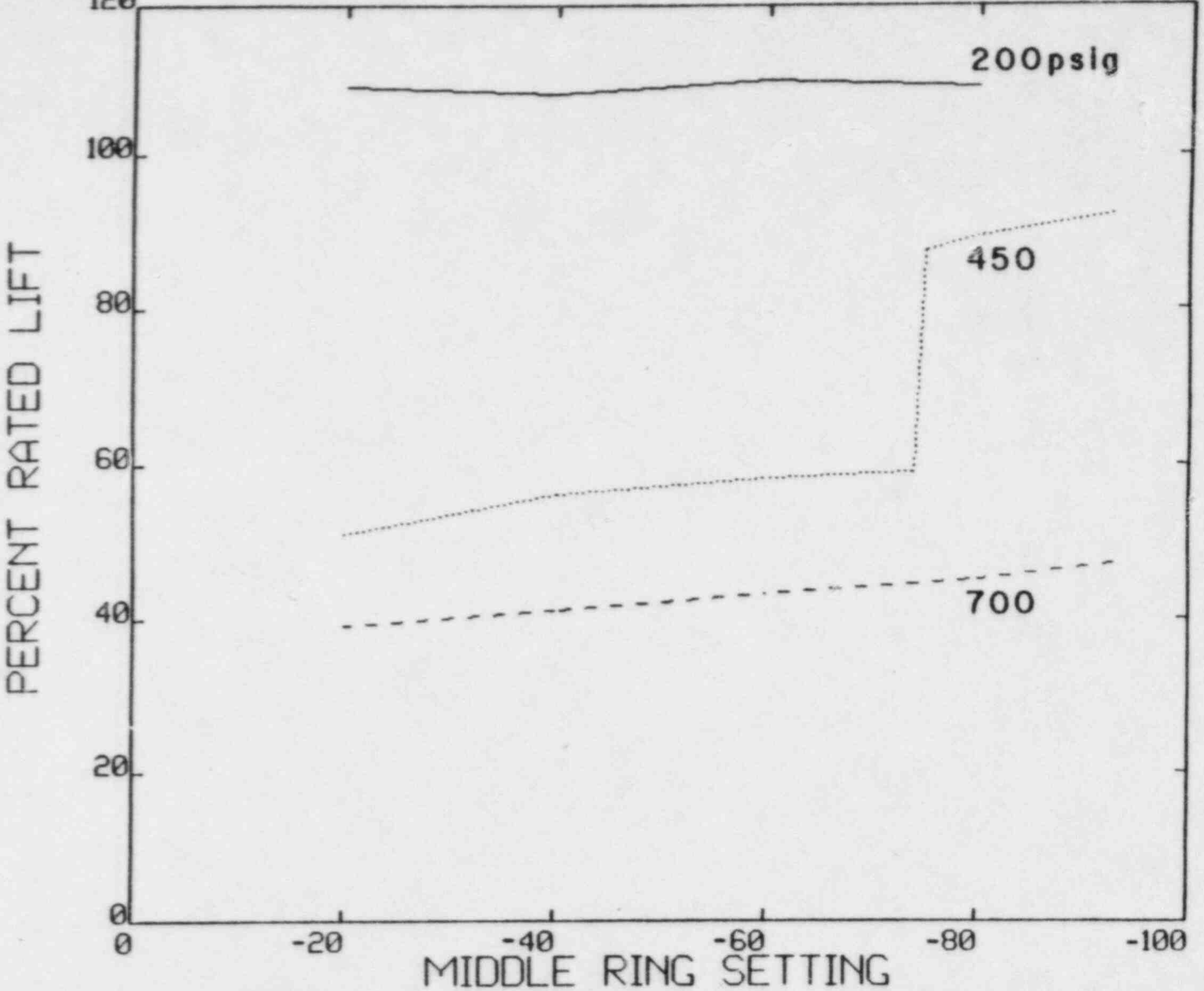


Figure 3-5b. Stem lift as a function of middle ring position and maximum back pressure for the Dresser 31759A - lower ring setting is +8 notches

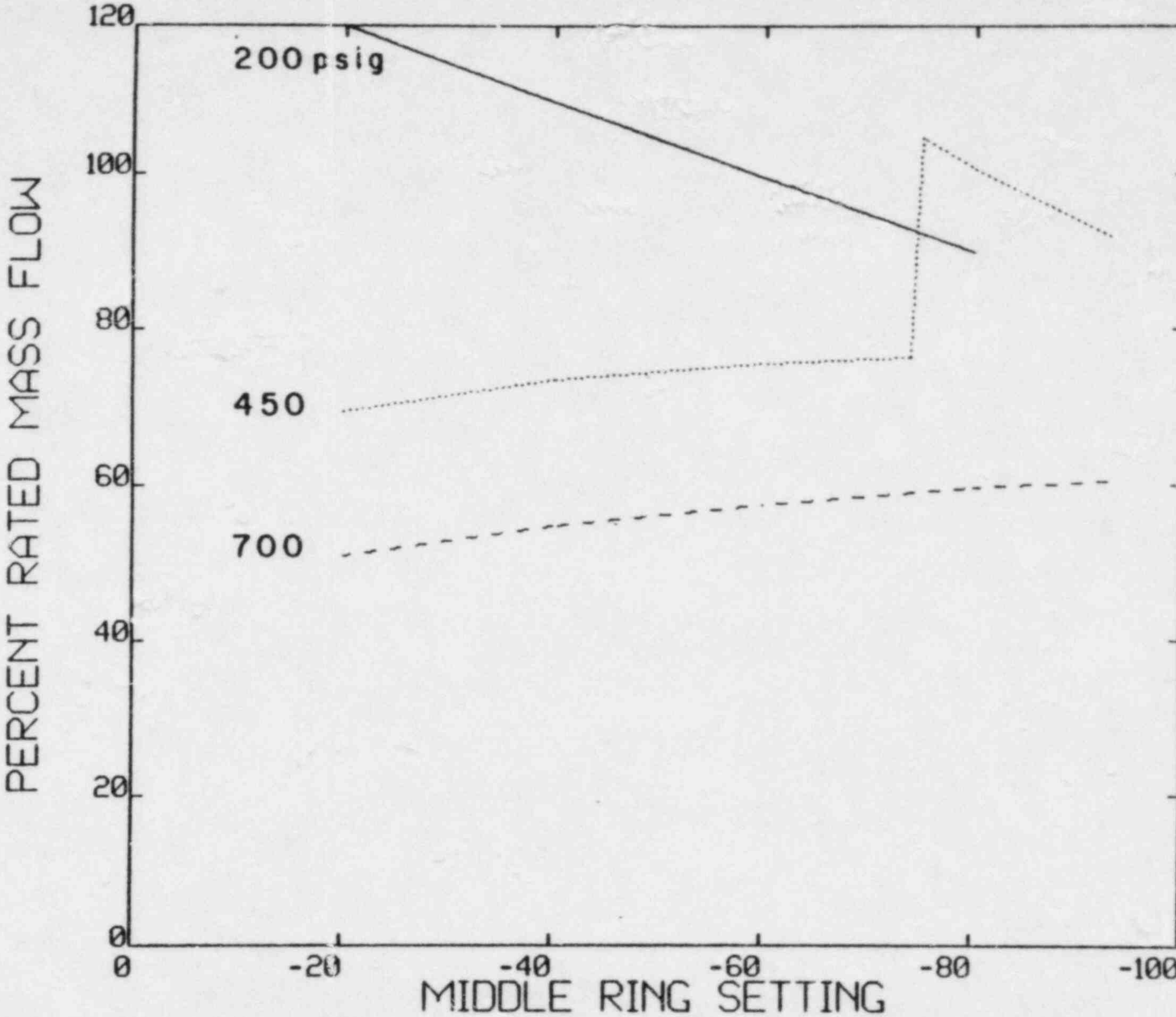


Figure 3-5c. Mass flow as a function of middle ring position and maximum back pressure for the Dresser 31759A - lower ring setting is +8 notches

Two other points are also important when interpreting Figures 3-4 and 3-5. One is recognition of the relationship between the hydrodynamic force balance and the static lift position of the Dresser valve. For strong hydrodynamic force (obtained with high pressurizer pressure, high middle ring settings or weak back pressure effects, for example) the static lift position of the Dresser valve will be above 80 percent rated lift. For weaker hydrodynamic force (obtained with decreasing pressurizer pressure, smaller middle ring settings or stronger back pressure effects, for example) the static lift position changes to below 50 percent rated lift. Dynamic simulation of the Dresser valve with decreasing pressurizer pressure (for example) will exhibit valve stem behavior that shows a rapid change as the static lift position changes from 80 percent to 50 percent rated lift. This effect may be seen near 50 seconds in the simulation in Figure 3-2. REV.1

In effect, there are no reasonable hydrodynamic force conditions that will allow the Dresser valve to maintain a lift position between about 50 percent and 80 percent rated lift. This behavior is reflected in Figures 3-4 and 3-5 for variation in middle ring setting (at 3 percent accumulation) in the rated lift and mass flow rate for the 450 psig curve. Providing additional valve lift through the middle ring setting allows the valve to achieve the higher static lift position (occurring between -20 and -40 middle ring notches for the 31739A and -60 and -80 for the 31759A). Caution must therefore be exercised when interpolating between curves in Figures 3-4 and 3-5.

The second point involves the interpretation in the COUPLE code of the valve exit area (graphically presented in Figure 2-2). The effective exit area is calculated by multiplying the maximum exit area (determined by the ring positions and r_p) by the cosine of the exit angle. As the Dresser valve leaves the full lift position, the minimum area through the valve (momentarily occurring at the exit area) increases because the cosine of a smaller angle is a larger value. This feature of the COUPLE code is illustrated in Figure 3-6. Mass flow rate can then increase above its full lift value as the valve leaves full lift. Thus, the 450 psig curve at less lift than the 200 psig curve can flow higher mass flow rate.

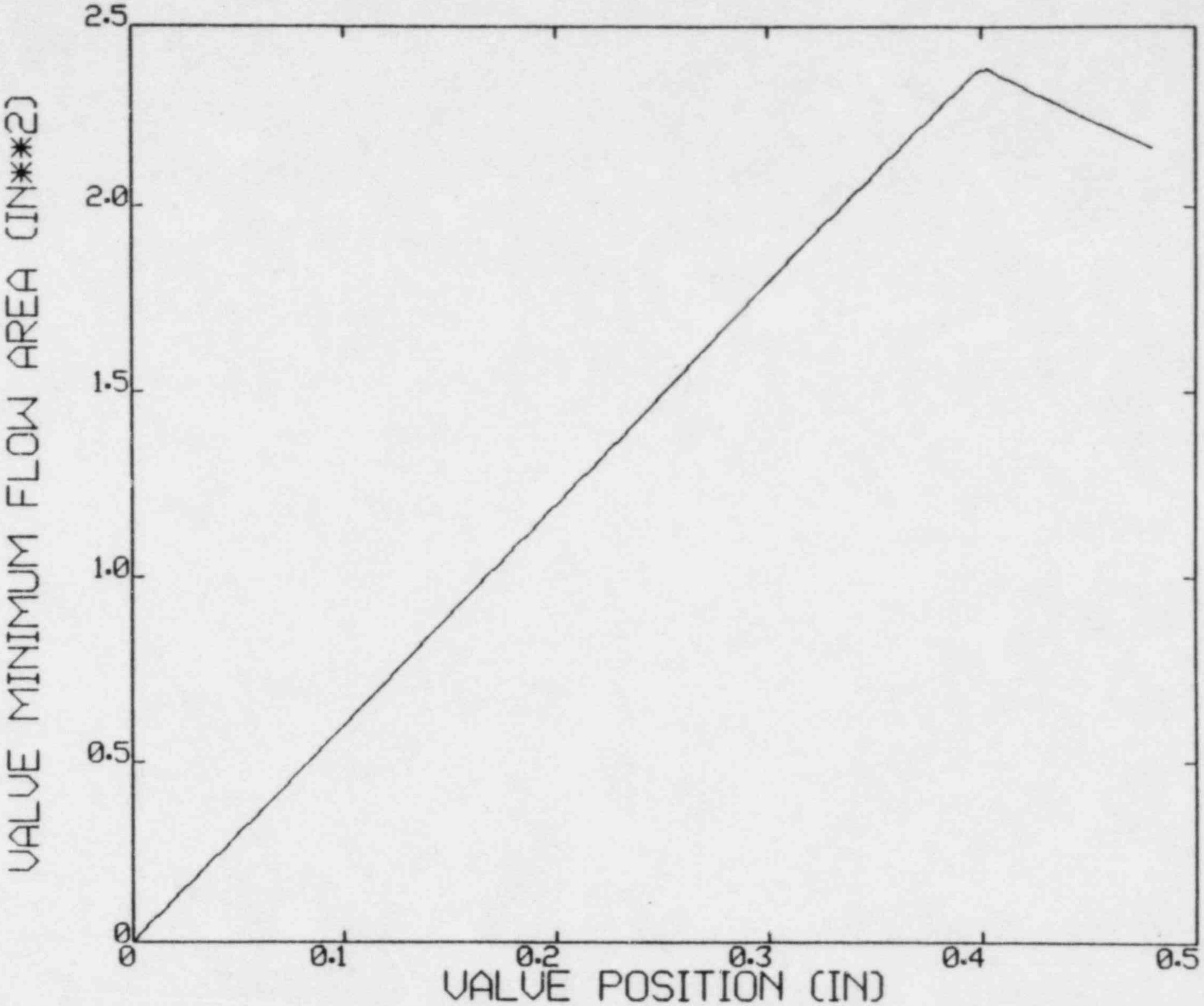


Figure 3-6. Minimum flow area through a Dresser 31739A valve as a function of stem position - lower ring setting is +8 notches; middle ring setting is -40 notches

It should also be noted that the 200, 450 and 700 psig maximum back pressure curves were generated using the mass flow rates given in Table 3-1. Extension to other mass flow rates and pressurizer pressures must take into account the conversion Eqs. (2-2) and (2-3). It is unlikely that a simple transformation will permit any arbitrary set of data to be positioned on Figures 3-4 and 3-5.

4. SELECTION OF NOMINAL RING POSITIONS FOR WATER RELIEF ANALYSES

At the request of Babcock & Wilcox, plant-specific analyses were performed to identify nominal ring positions which could be used in the analyses of valve performance during conditions of subcooled water relief. These analyses made use of plant-specific back pressures as indicated in Table 4-1; the assumed mass flow rates which serve as the bases for these back pressures are also shown in Table 4-1.

The selection of the middle ring positions was based on the criteria of achieving rated mass flow rate through the plant-specific valve. To achieve this result the valve lift position at full back pressure has to be above 80% rated lift. The selected middle ring settings are shown in Table 4-2, along with the achieved lift, mass flow rate and blowdown. The driving pressurizer pressure is shown in Figure 4-1, and the predicted plant-specific stem positions and mass flow rates are shown in Figures 4-2 to 4-7. REV.1

Middle ring selection for the 31759A valves (ANO-1 and Rancho Seco) required the strongest negative setting to offset the back pressure effect acting in the larger valve. Since the strongest tested negative setting in the 31739A was -80 notches (run 1008 from Ref. 1), it was assumed that the untested 31759A could have its middle ring placed at a setting corresponding to the same scaled physical distance below the valve seat plane. This results in the -93 middle ring setting shown in Table 4-2. Additionally, to achieve rated mass flow at the specified back pressures, both 31759A valves required 7% accumulation. In these simulations the 2575 psig pressurizer pressure, shown in Figure 4-1, is replaced by 2675 psig to 30 seconds, and by a vertical line connecting 2675 and 2575 psig at 30 seconds. REV.1

Figure 4-2 for ANO-1 is representative of the plant-specific results shown in Figures 4-2 to 4-7. At initiation of the COUPLE run, the valve stem lifts to rated lift, then decreases to a position above 80% rated lift (TMI-1 and CR-3 remain at 100% rated lift) as the back pressure is imposed fully through Eq. (2-1). With the reduction in pressurizer pressure above 30 seconds, the

TABLE 4-1

Plant-Specific Valve Characteristics

Plant	Valve Model	Back Pressure (psia)	Safety Valve Flow (lbm/hr)
Arkansas Nuclear One Unit 1	31759A	595	434,440
Crystal River Unit 3	31739A	520	360,000
Midland Units 1 and 2	31739A	567	341,700
Oconee Nuclear Station Units 1, 2 and 3	31739A	578	370,000
Rancho Seco	31759A	500	391,000
Three Mile Island Unit 1	31739A	500	370,970

REV.1

TABLE 4-2

Valve Performance at Ring Settings Selected for Water Analysis

Plant	Middle Ring Setting (notches)	% of Rated Lift*	% of Rated Mass Flow*	% Blowdown	
Arkansas Nuclear One Unit 1	-93	80.5	102.8	8.5	
Crystal River Unit 3	-50	100.0	101.7	13.0	
Midland Units 1 and 2	-60	91.5	100.4	12.4	
Oconee Nuclear Station Units 1, 2 and 3	-50	97.6	103.1	12.6	
Rancho Seco	-93	85.4	100.1	8.6	REV.1
Three Mile Island Unit 1	-50	100.0	101.7	13.6	

* All results other than ANO-1 and Rancho Seco are for 3% accumulation. ANO-1 and Rancho Seco results are shown for 7% accumulation REV.1

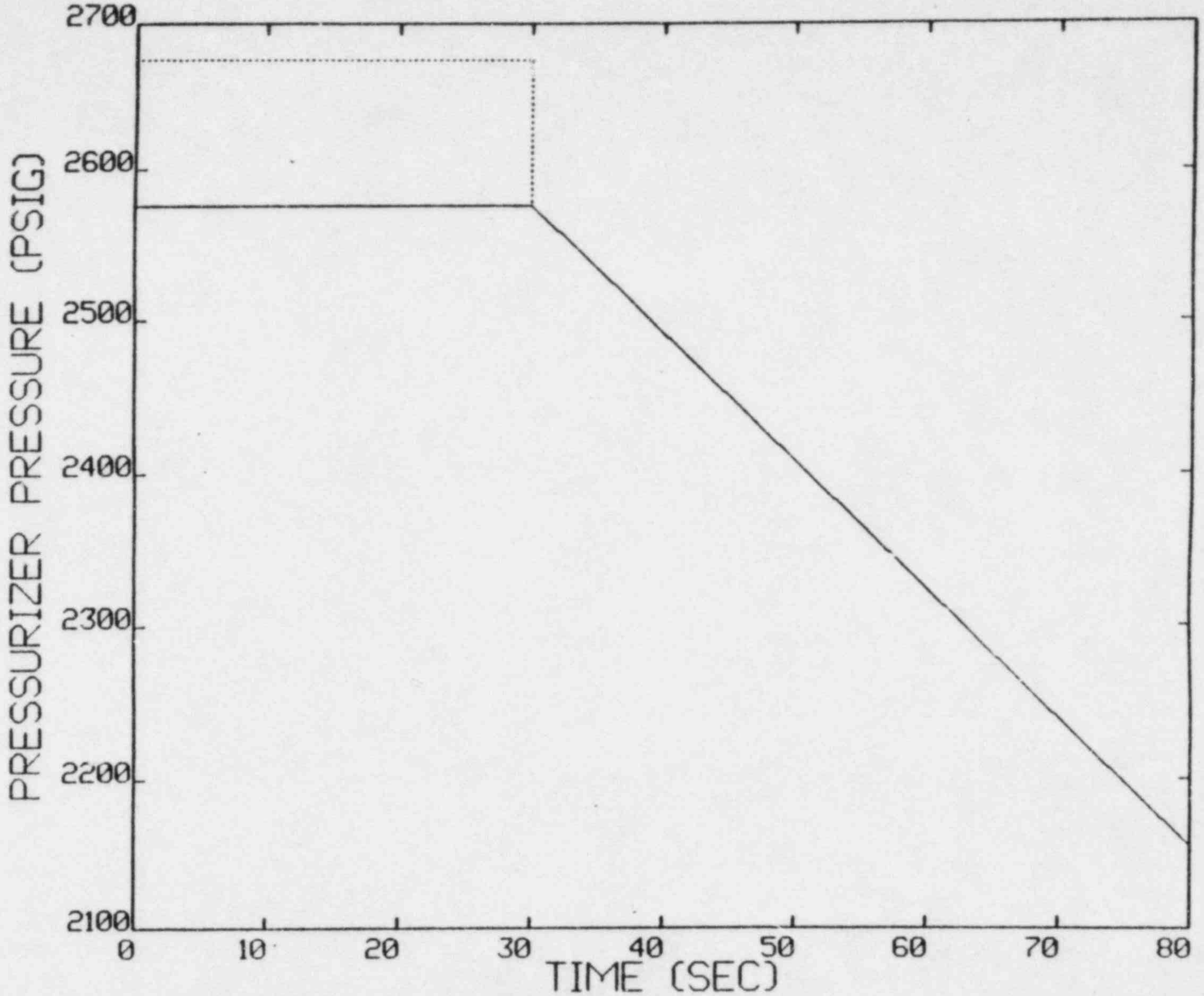


Figure 4-1. Assumed pressurizer pressure time history for 3% accumulation (———) and 7% accumulation (····)

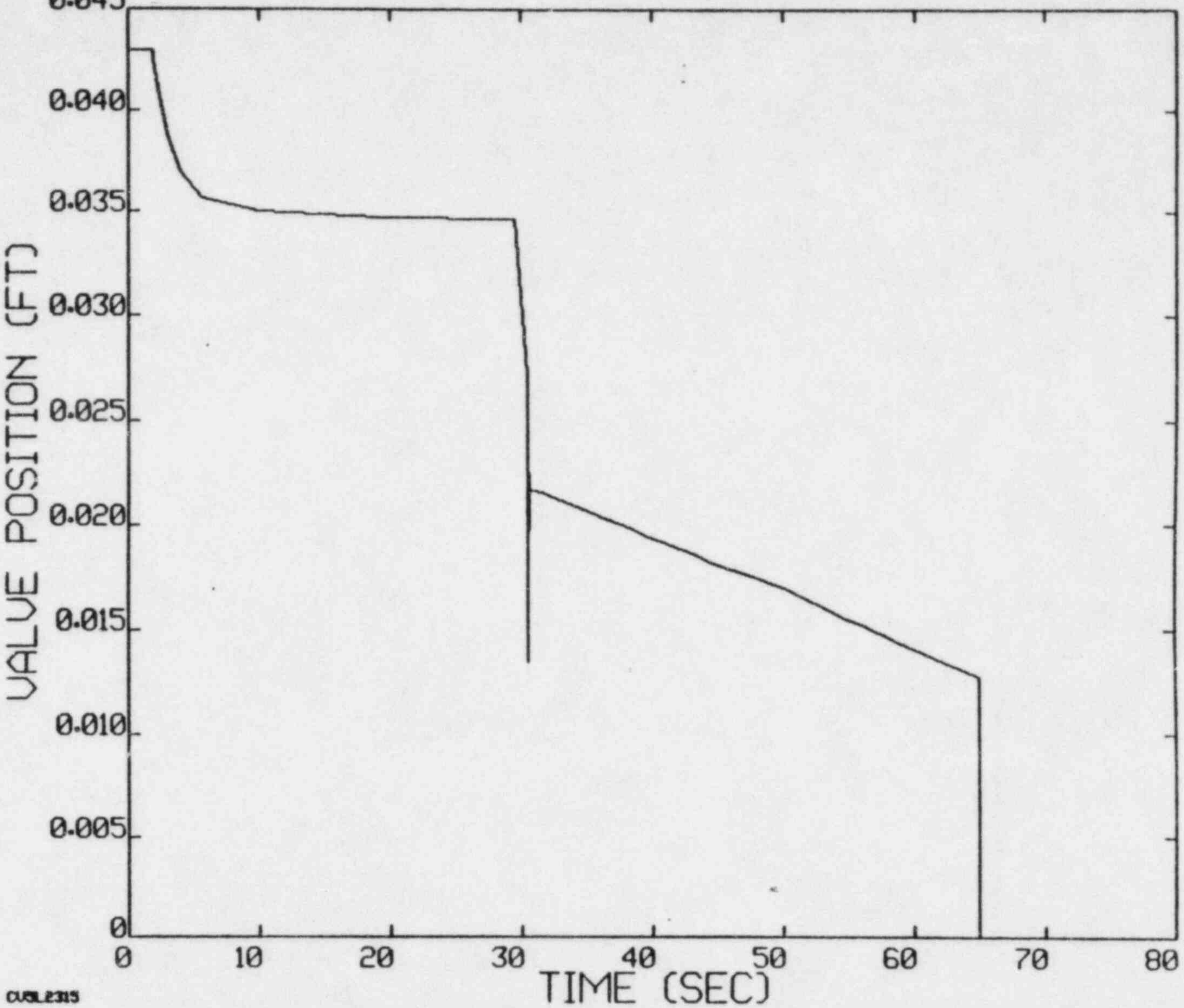
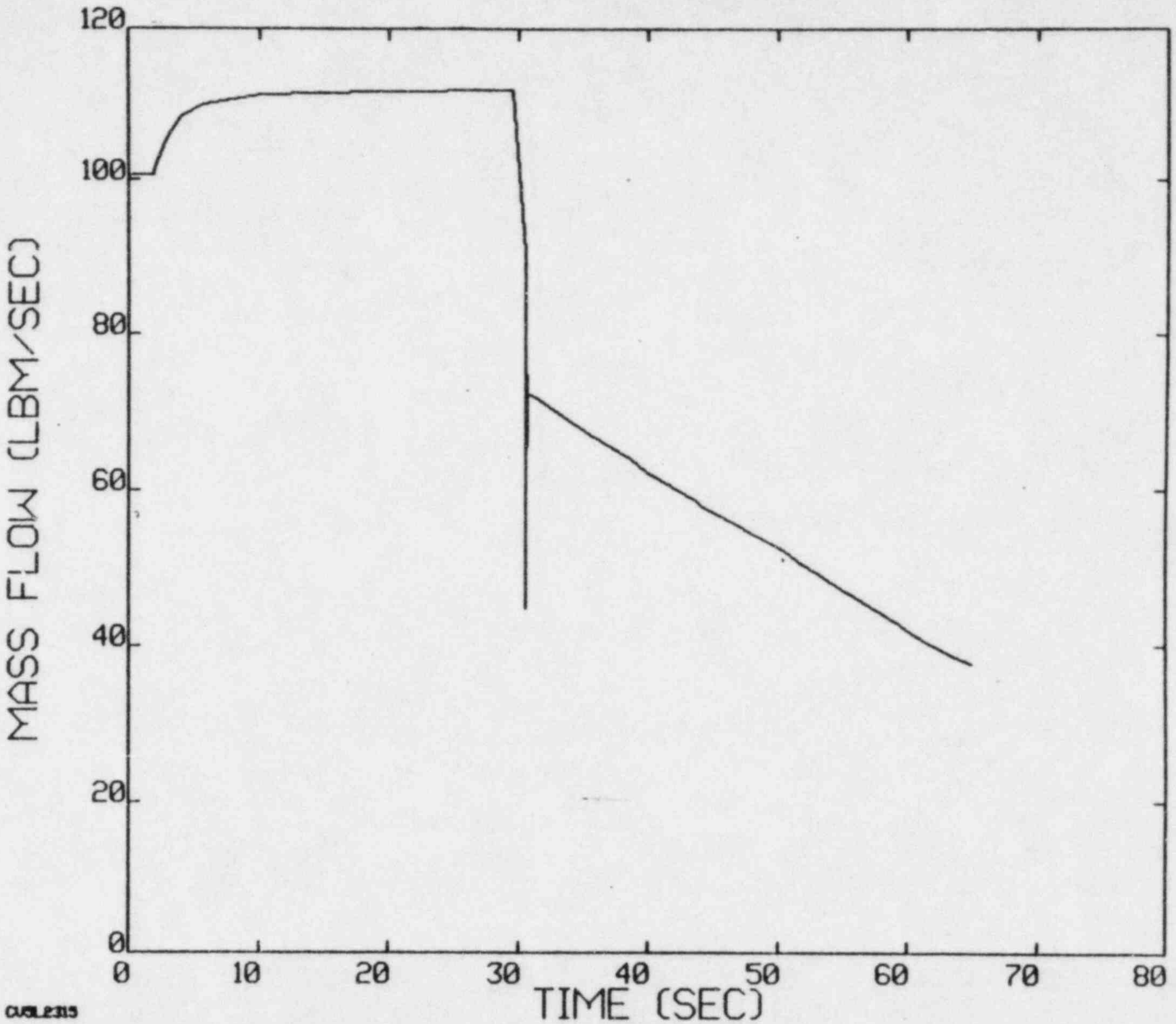


Figure 4-2a. Predicted actual valve stem position for the Dresser 31759A in Arkansas Nuclear One Unit 1 - lower ring setting is +8 notches; the middle ring setting is -93 notches; the initial accumulation is 7%



CVSL2315

Figure 4-2b. Predicted actual mass flow for the Dresser 31759A in Arkansas Nuclear One Unit 1

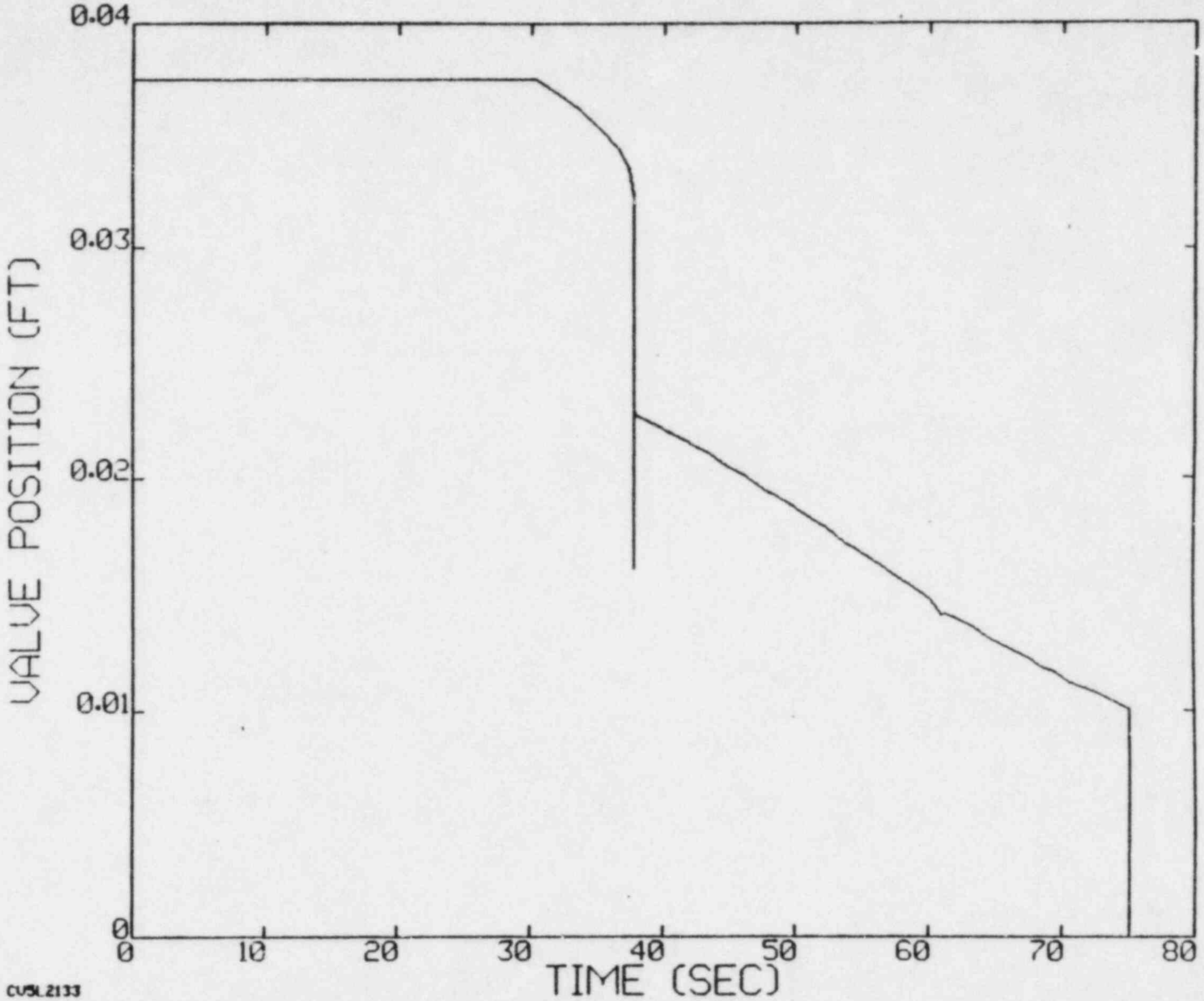


Figure 4-3a. Predicted actual valve stem position for the Dresser 31739A in Crystal River Unit 3 - lower ring setting is +8 notches; the middle ring setting is -50 notches

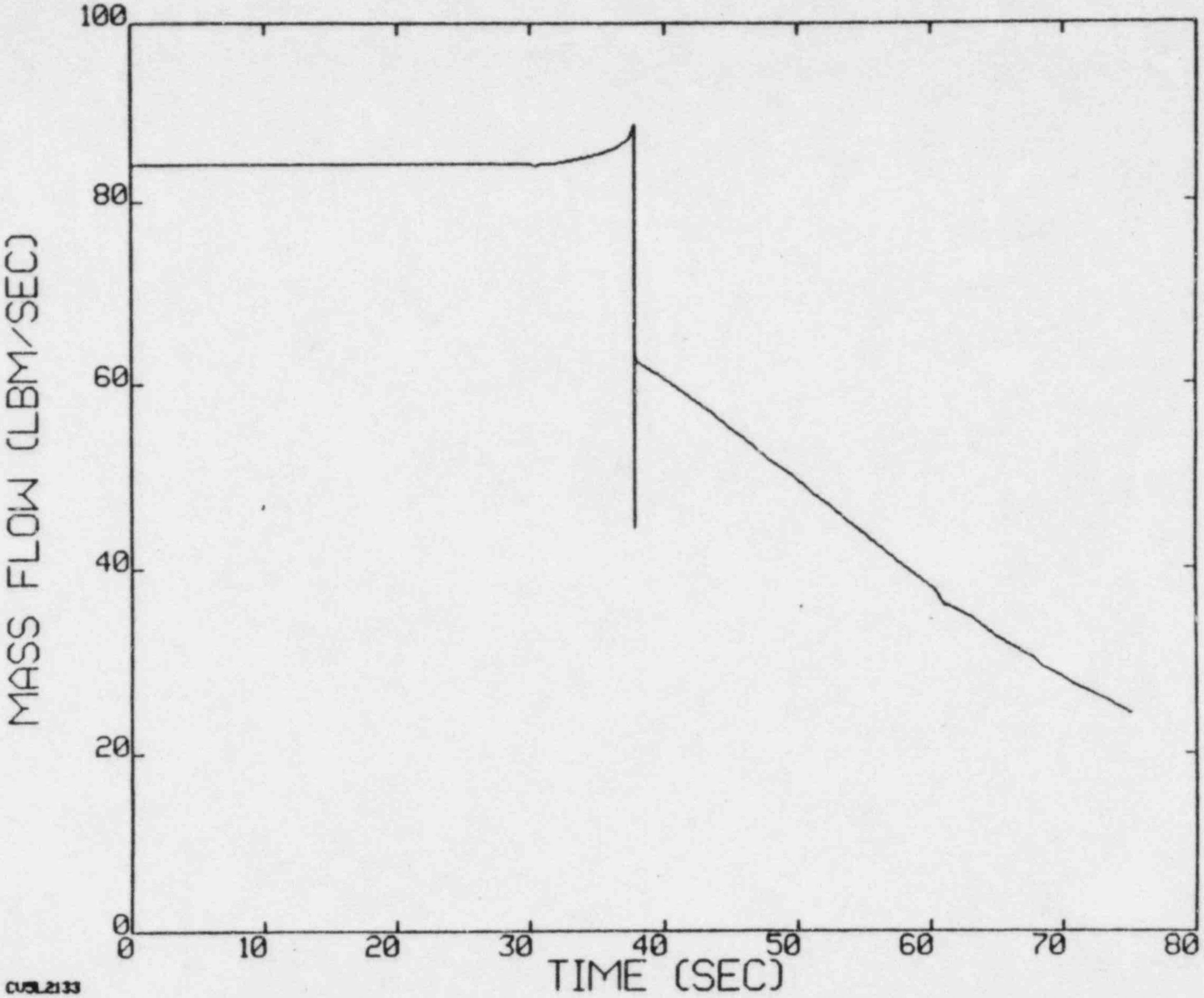


Figure 4-3b. Predicted actual mass flow for the Dresser 31739A in Crystal River Unit 3

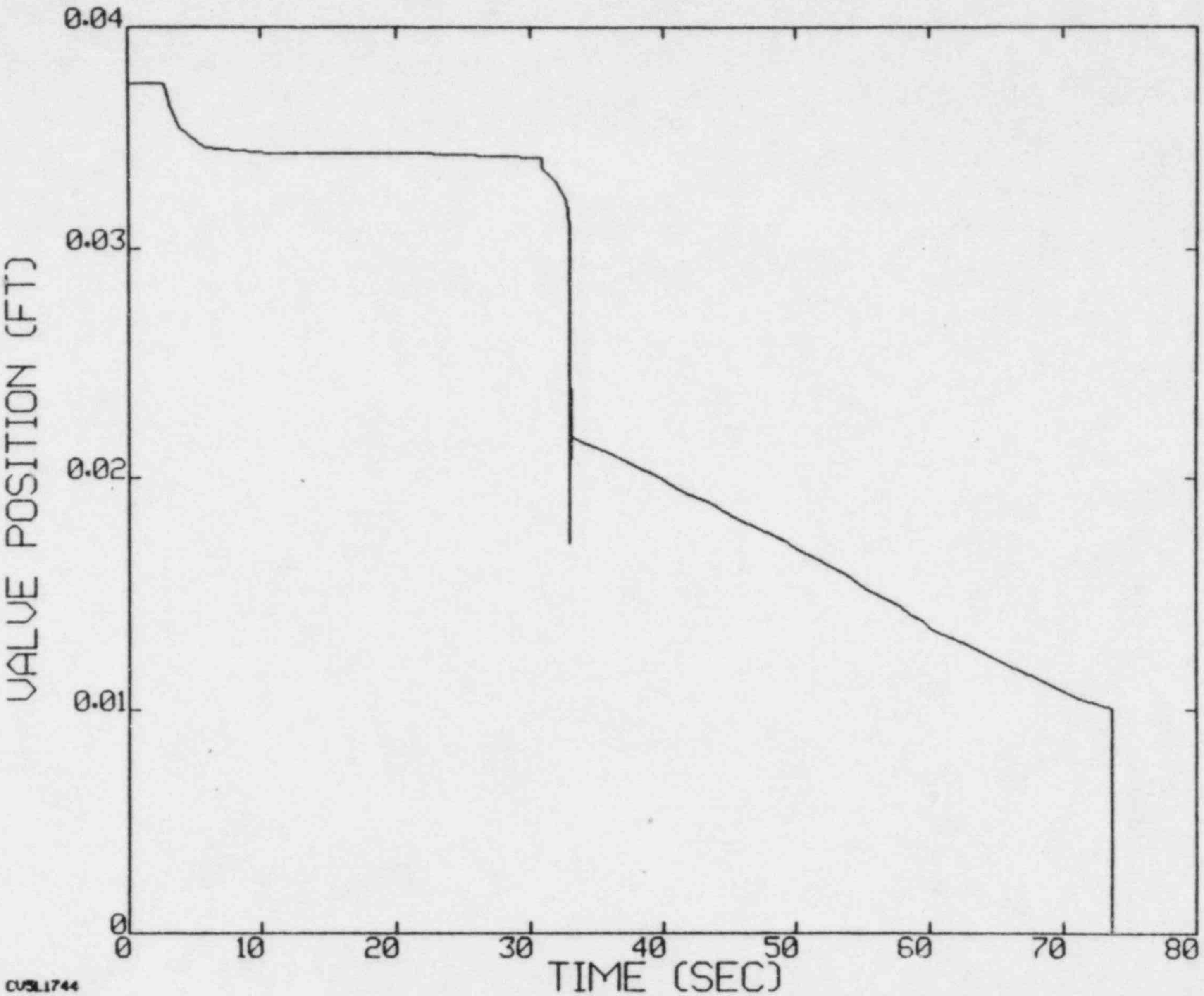


Figure 4-4a. Predicted actual valve stem position for the Dresser 31739A in Midland Units 1 and 2 - the lower ring setting is +8 notches; the middle ring setting is -60 notches

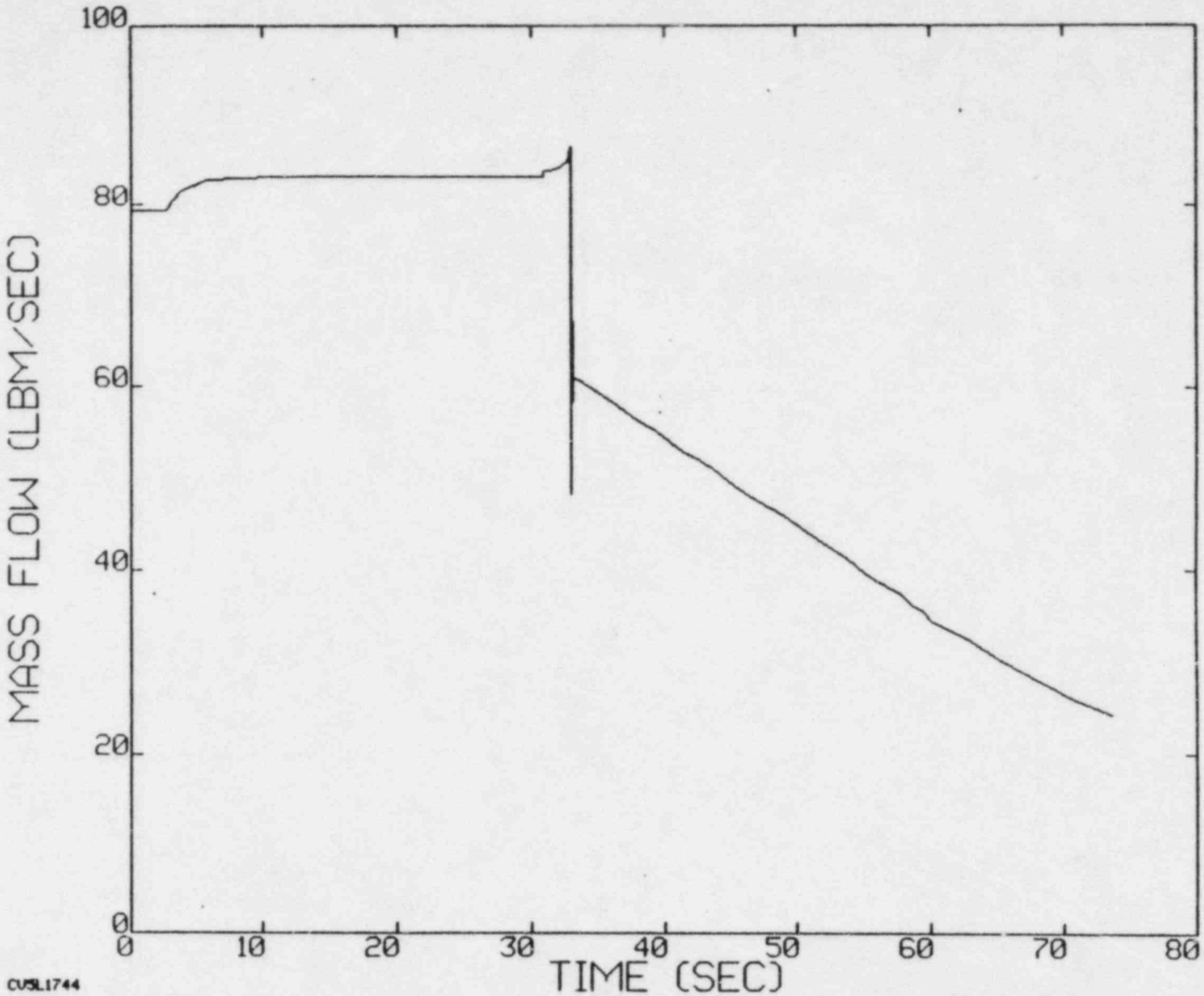
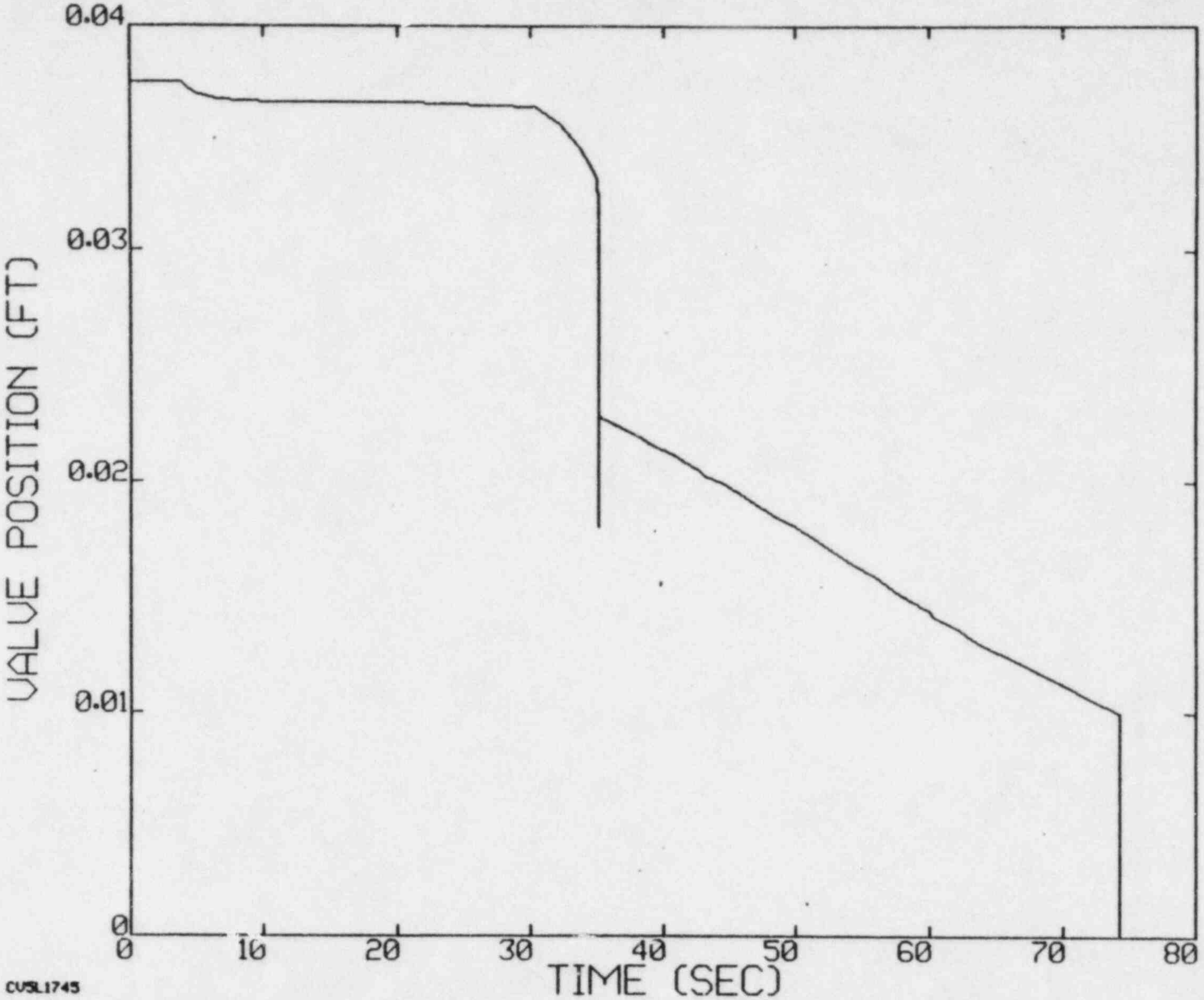


Figure 4-4b. Predicted actual mass flow for the Dresser 31739A in Midland Units 1 and 2



CVSL1745

Figure 4-5a. Predicted actual valve stem position for the Dresser 31739A valve in Oconee Nuclear Station Units 1, 2 and 3 - the lower ring setting is +8 notches; the middle ring setting is -50 notches

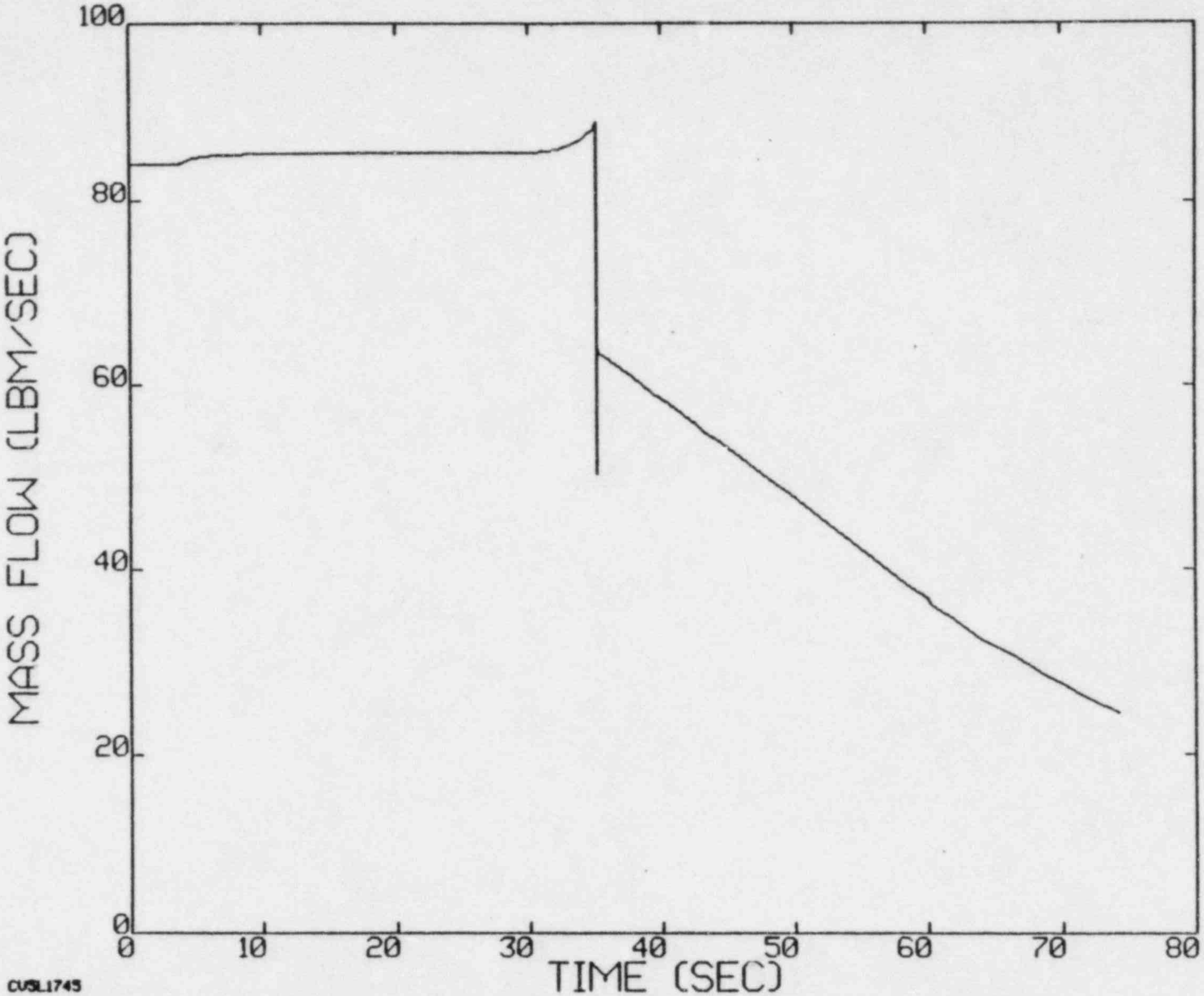
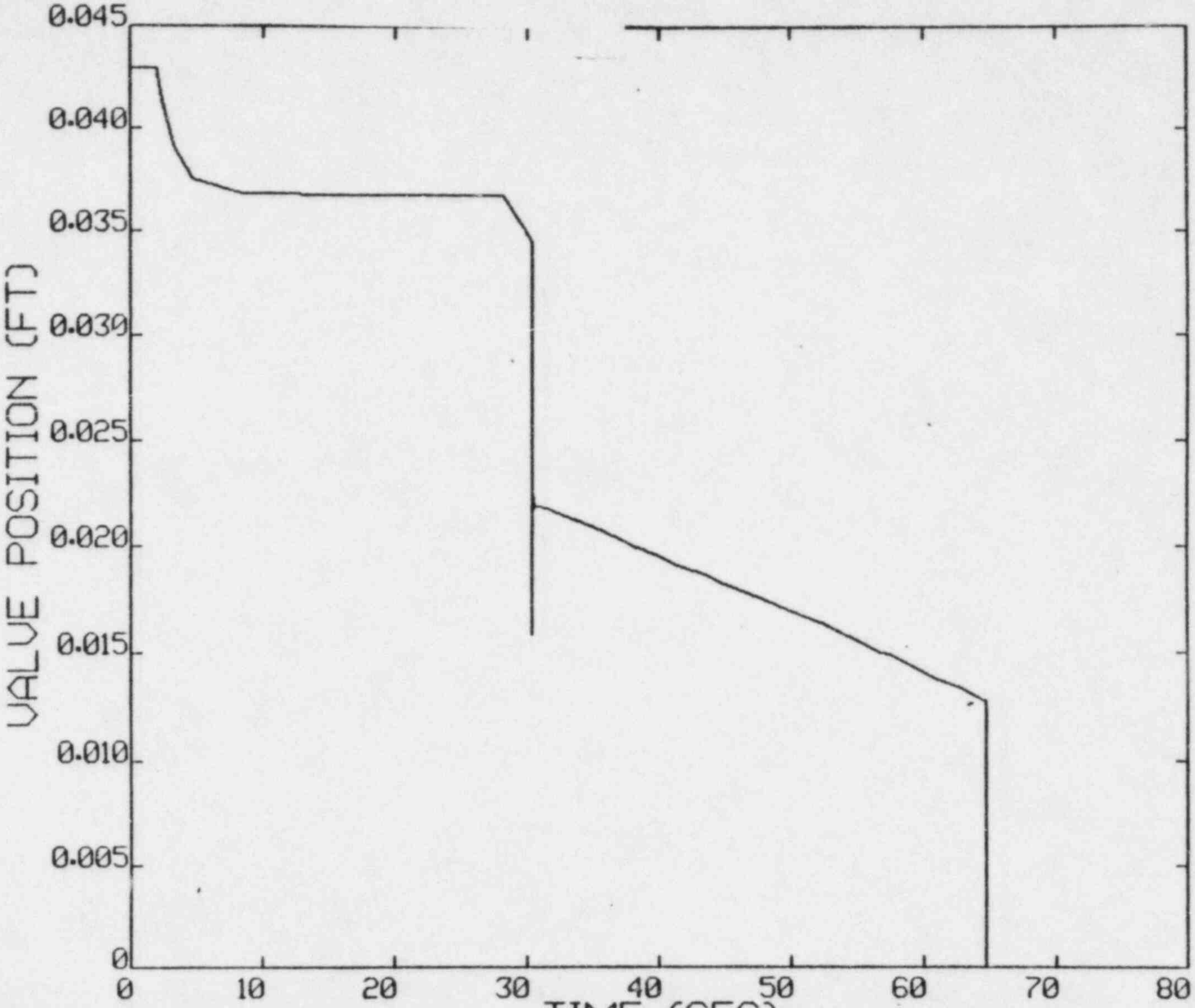


Figure 4-5b. Predicted actual mass flow rate for the Dresser 31739A valve in Oconee Nuclear Station Units 1, 2 and 3



CV5L2314

Figure 4-6a. Predicted actual valve stem position for the Dresser 31759A in Rancho Seco - lower ring setting is +8 notches; the middle ring setting is -93 notches

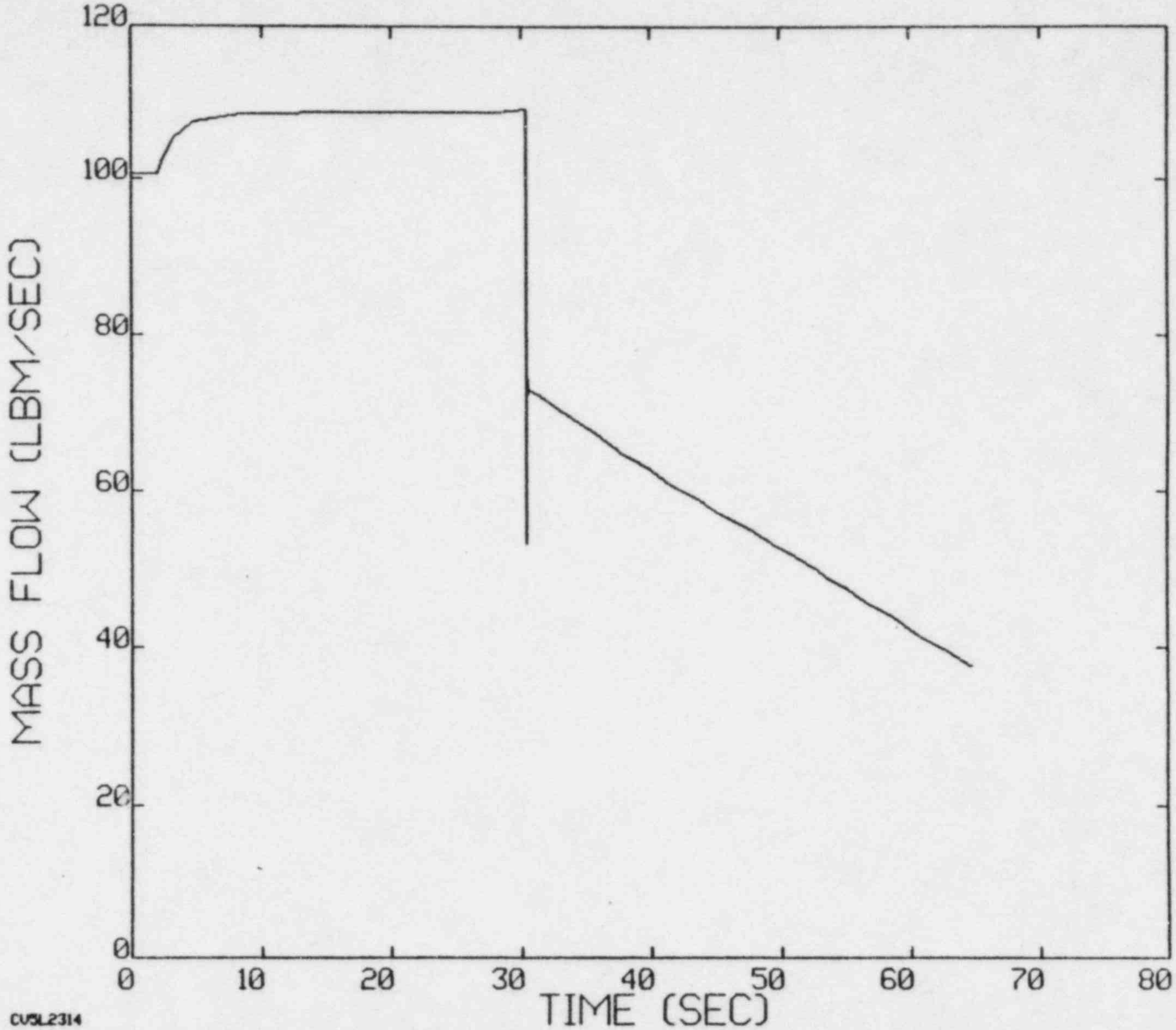


Figure 4-6b. Predicted actual mass flow for the Dresser 31759A in Rancho Seco

REV.1

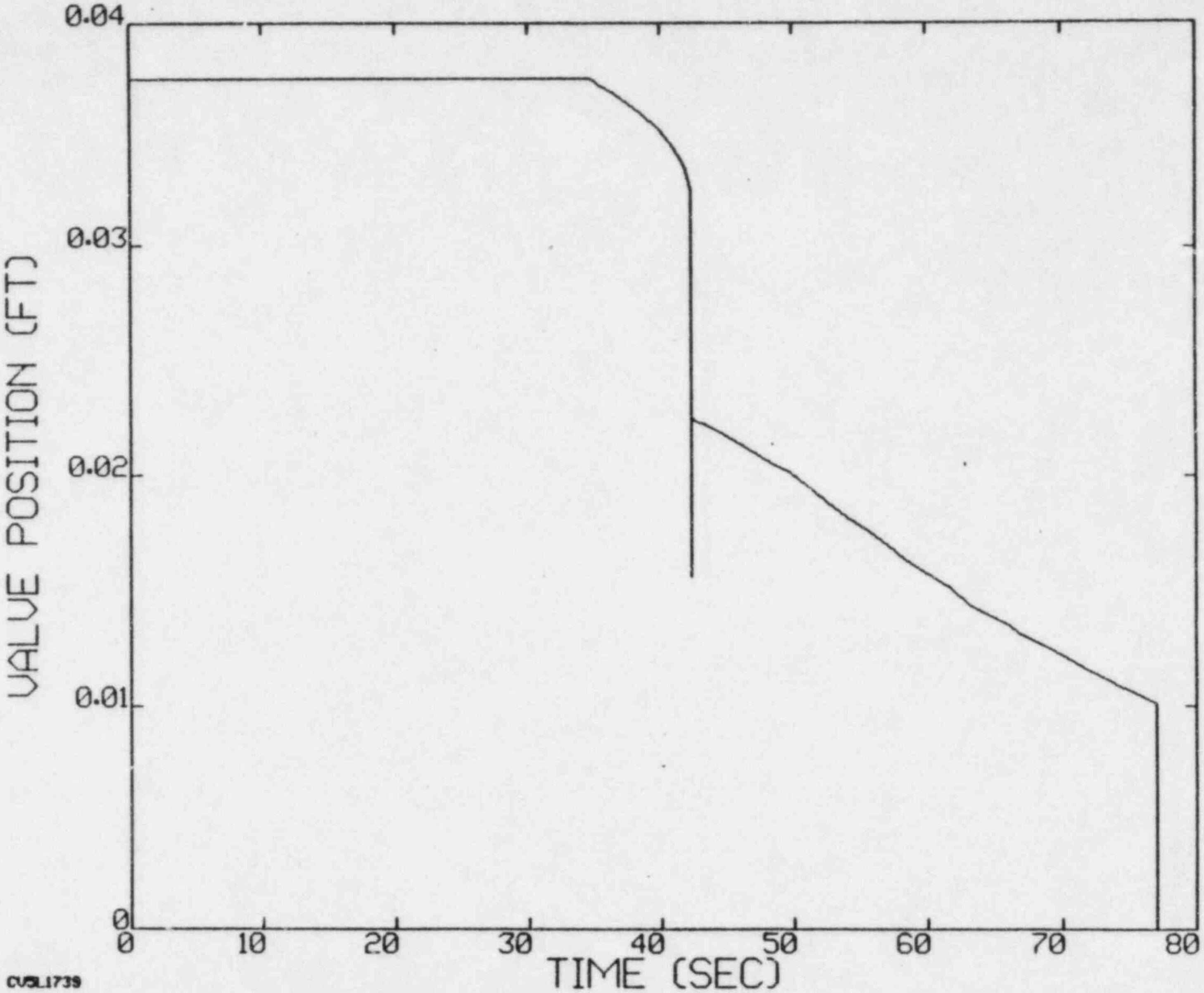


Figure 4-7a. Predicted actual valve stem position for the Dresser 31739A in Three Mile Island Unit 1 - lower ring setting is +8 notches; the middle ring setting is -50 notches

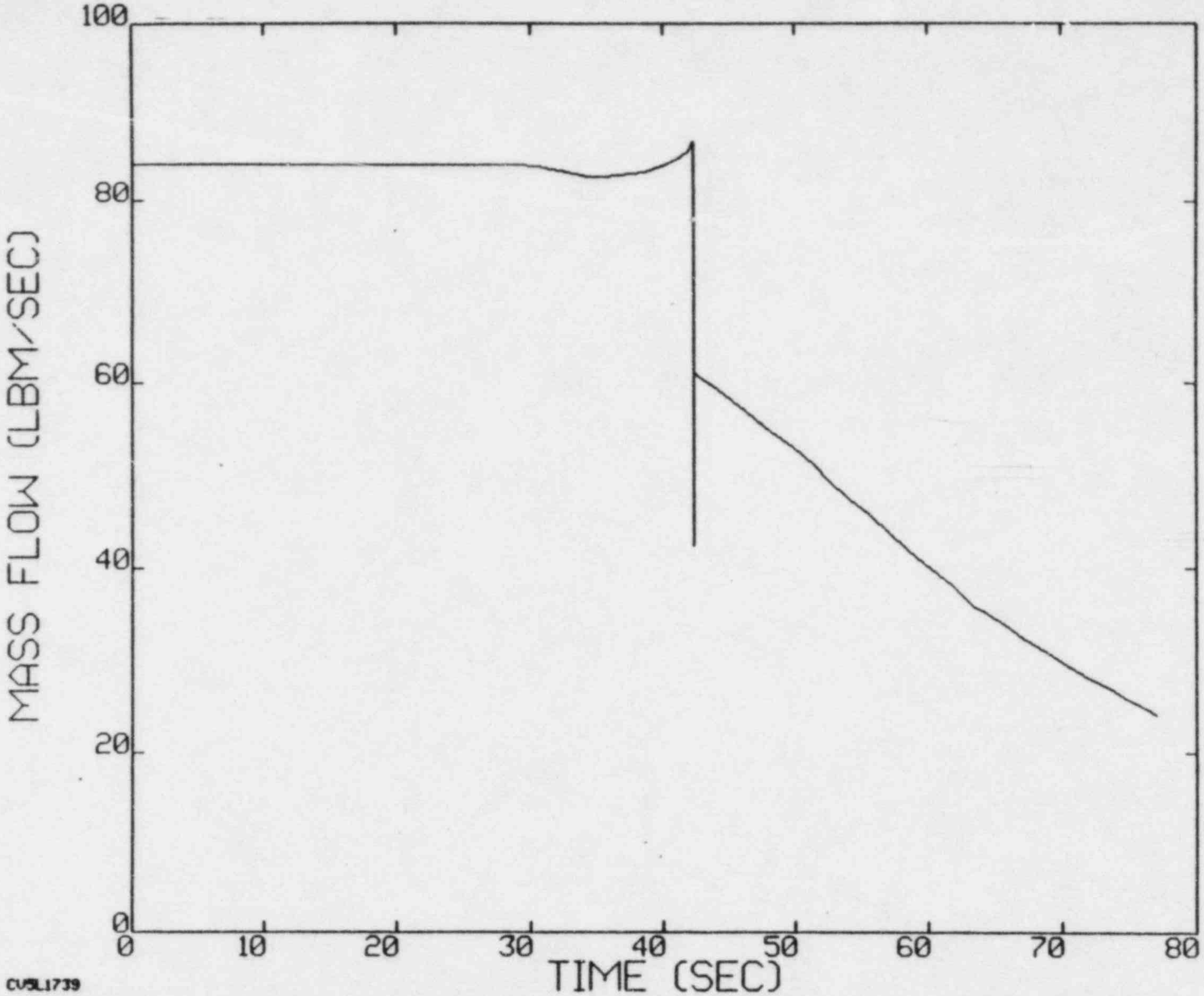


Figure 4-7b. Predicted actual mass flow rate for the Dresser 31739A valve in Three Mile Island Unit 1

valve stem falls to an intermediate position between 40% and 50% rated lift, then decreases monotonically until 25% actual lift is achieved, at which point the valve closes.

The mass flow rate exhibits the same trends as the valve stem except that as the valve stem decreases from rated lift, the mass flow rate increases. This trend is in response to an increase in the minimum valve area with decreasing lift (discussed previously in Figure 3-6 and examined in more detail in the Appendix). The maximum mass flow rate is achieved as the valve falls to its intermediate position, but this brief maximum is a result of the flow path assumptions in the COUPLE code, and was disregarded when filling out Table 4-2 for rated lift and rated mass flow rate. REV.1

5. REFERENCES

1. "EPRI/C-E Safety Valve Test Report, Interim Report," (ten volumes), T.E. Auble (EPRI Project Manager), July 1982.

2. "Coupled Valve Dynamic Model, for Isentropic, Two-Phase and Subcooled Discharge, Technical Description," C.D.I. Tech Note No. 83-6, prepared for Participating PWR Utilities and Electric Power Research Institute, May 1983.

3. Thermodynamic Properties of Steam, J.H. Keenan and F.G. Keyes, John Wiley and Sons, 1936, pp. 89.

4. "Flow of Fluids Through Valves, Fittings and Pipe," Crane Company Technical Paper No. 410, 1980.

6. APPENDIX

Figures 4-2b, 4-3b, 4-4b, 4-5b, 4-6b and 4-7b for actual mass flow through the Dresser 31739A and 31759A valves all exhibit a mass flow increase as the valve stem decreases to about 80% rated lift. As discussed in the main body of this report this increase in mass flow is a result of the valve exit area formulation, which permits the valve minimum area to increase slightly as the valve disc leaves full lift (as illustrated in Figure 3-6). This Appendix reexamines the valve flow area modeling with the anticipation of correcting this behavior.

As discussed in Section 2, the fluid exit angle is assumed to be equal to an angle formed by a tangent drawn along the stem position to the middle ring (geometrically illustrated as θ_B in Figure 2-2). This assumption of exit angle leads to an enhanced prediction of blowdown above the results demonstrated in Ref. 2. However, an outgrowth of this assumption is that the minimum flow area is placed at the valve exit plane when the valve stem is above about 85% of full lift. Between 85% lift and full lift, as the valve stem position increases, the predicted mass flow decreases because of trigonometric considerations of the exit angle. Thus, as the valve comes off full lift during a blowdown, the mass flow may be seen to rise slightly.

Because the fluid flow path through the valve is tortuous, an idealized path was specified with the exit angle constructed geometrically based on a simple exit angle tangent argument. This model assumes that the valve exit angle continues to increase above 85% lift. An alternate assumption is to assume that the valve exit angle remains constant at the angle where the critical area first moves to the valve exit plane. This assumption would be consistent with assuming that the flow separates from the middle ring at that point, and will affect valve behavior only above about 85% lift (blowdown will be unchanged).

An examination of CR-3 using this revised exit formulation results in valve stem position and mass flow as shown in Figure 6-1 (to be compared with Figure 4-3). The above assumptions restrict the maximum exit angle by

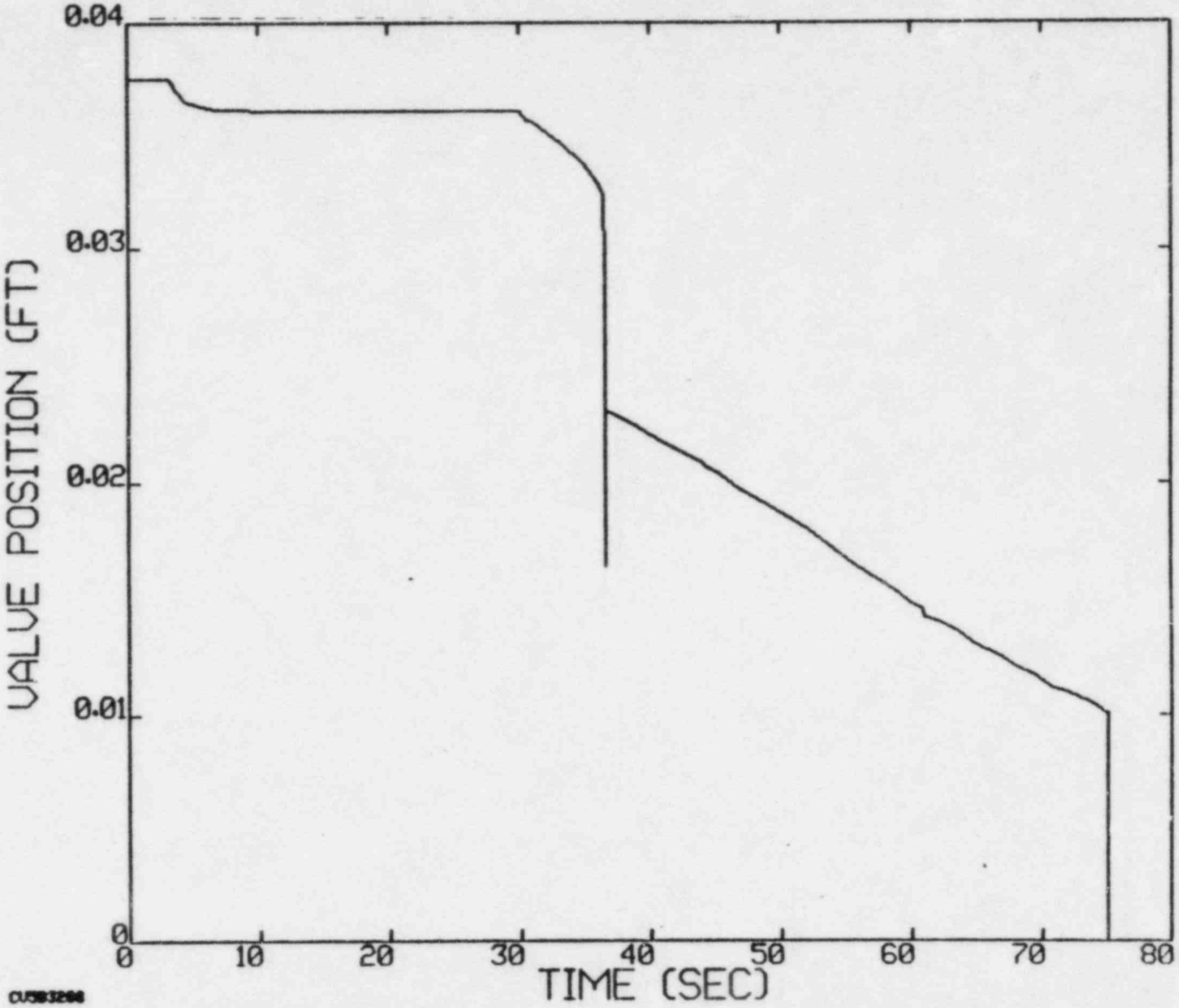


Figure 6-1a. Predicted actual valve stem position for the Dresser 31739A in Crystal River Unit 3 - the lower ring setting is +8 notches; the middle ring setting is -50 notches; the revised exit angle formulation is used

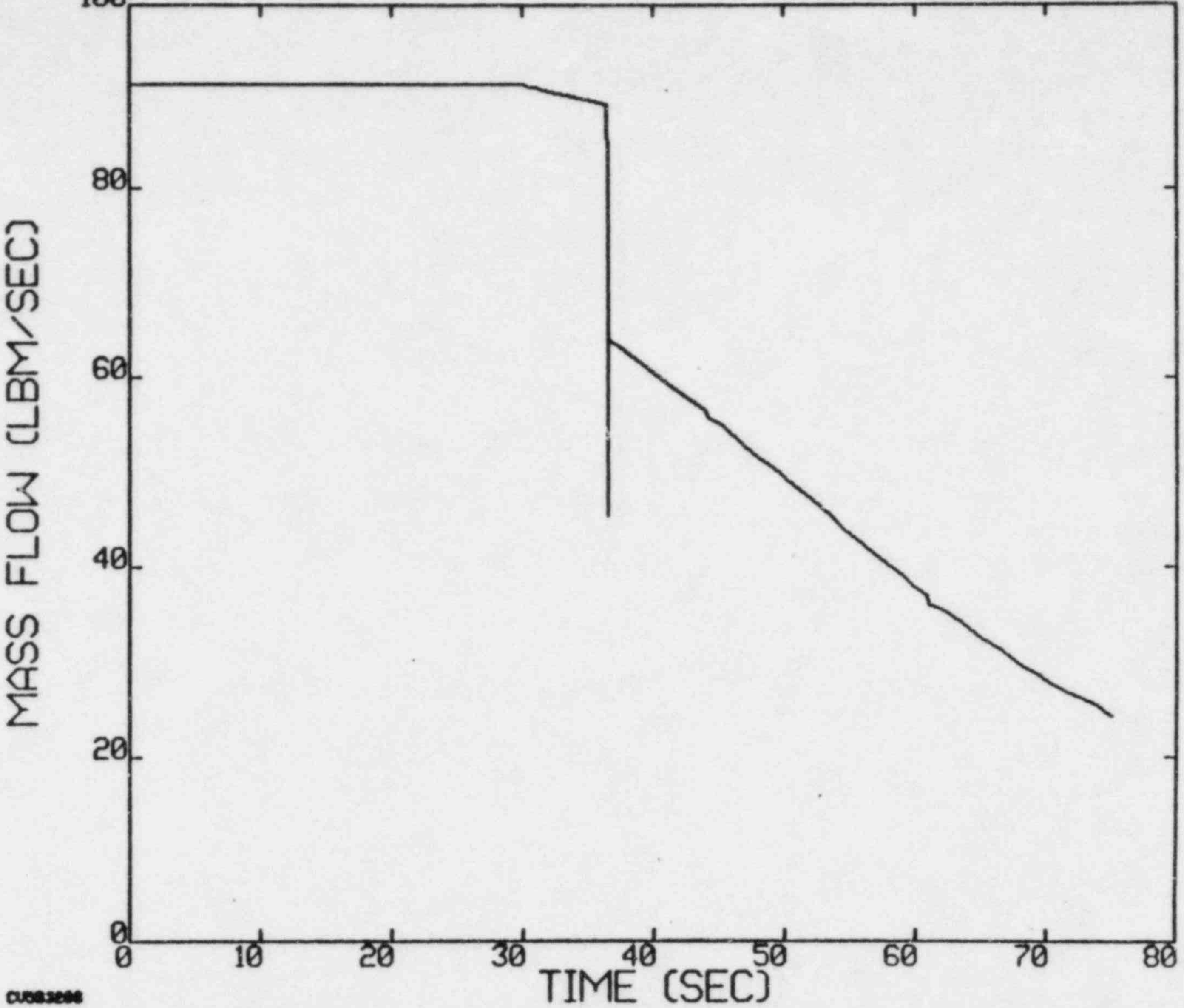


Figure 6-1b. Predicted actual mass flow for the Dresser 31739A in Crystal River Unit 3; the revised exit angle formulation is used

3.7 degrees (lowering the maximum angle by 6.8%), the maximum lift is decreased 4% of rated lift while the maximum flow is increased 8.7% of rated mass flow over the values cited in Table 4-2. The predicted mass flow is shown in Figure 6-1b.

Because the valve loses some of its lift at full back pressure, it was decided to also examine ANO-1. The revised exit angle requires 8% accumulation to maintain acceptable lift and mass flow at the -93 middle ring setting for the Dresser 31759A valve.