REVISED VACUUM BREAKER VALVE RESPONSE FOR FERMI-2

REVISION 0

Prepared by

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SUMMARY

Previous predictions of vacuum breaker valve response for Fermi-2 were made using a conservative valve dynamic model. Because conservatism is ensured by using a design loading function greater than that expected, Detroit Edison requested that the conservatism be removed from the valve model itself.

During FSTF run SD-A, the vacuum breaker position time history was measured, so data from this run allowed a parameter study to be undertaken to minimize conservatism by adjusting the strength of the Bernoulli suction term.

The Fermi-2 valve response was recomputed with the adjusted model, and the maximum impact velocities are reduced by 40% from those predicted by the original model.

MODEL CALIBRATION AND RESULTS

The single disc nonlinear analytical valve dynamic model with leakage (Ref. 1) uses the differential pressure forcing function across the vacuum breaker, but also includes the effect of torque reduction as a result of valve flow.

When the valve is closed, the hydrodynamic torque on the disc is

$$\tau = \iint_{r<a} \Delta p \; d_H \; r dr \; d\theta$$

where $d_H = a - r \cos\theta$ and Δp is the pressure difference $p_u(t) - p_d(t)$ (see Figure 1). However, when the vacuum breaker opens, the Δp across the valve disc is no longer this pressure forcing function because of the flow effects. The reduced hydrodynamic torque is estimated by superimposing valve motion effects and flow effects assuming no motion. A linear analysis of the pressure on either side of the valve allows spatial harmonics of the pressure and velocity fields around the valve disc to be determined. These are used to determine the strength of the one-dimensional source/sink at the disc circumference which models the flow. The flow then determines terms for the Bernoulli torque, τ_B, and reduced static pressure differential torque near the open edge, τ_E.

Because the methodology was developed using a small perturbation approach (although for large openings upstream dynamic pressure is taken into account) and requires some approximation of integrals in evaluating the Bernoulli torque, the strength of this term must be calibrated by comparing predictions to experimental results. Thus, the hydrodynamic torque in the model is given by

$$\tau = \pi a^3 \Delta p + f \cdot (\tau_B - \tau_E)$$

where f is an adjustable model parameter.

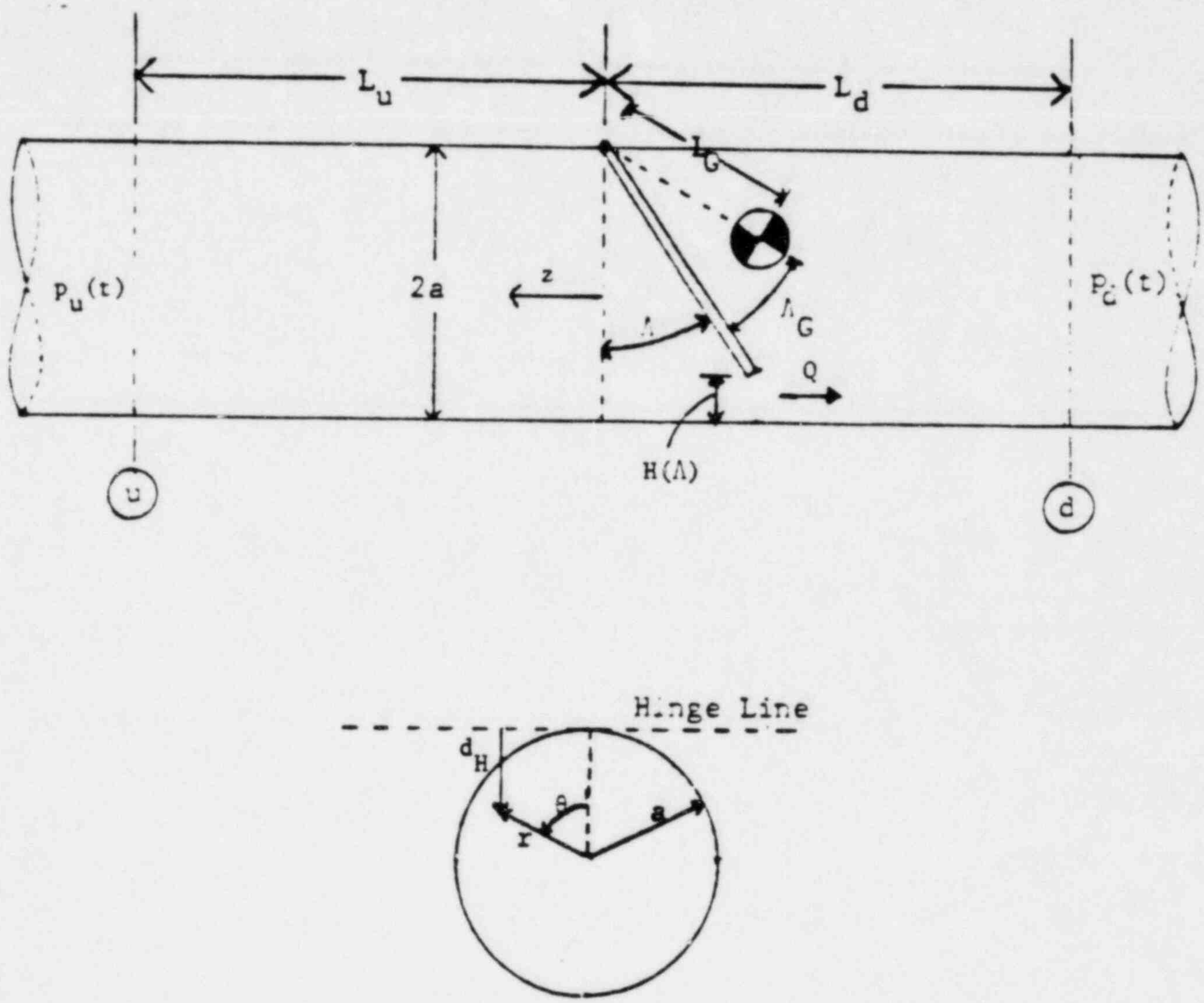

Figure 1. Nonlinear valve dynamic model geometry

During the Mark I FSTF run SD-A, the valve displacement time history in the GPE vacuum breaker was recorded as well as pressure time histories at the ring header. These data allowed the necessary model calibration to be performed. With $f = 1.00$, corresponding to the original model used for the previous Fermi-2 predictions under Detroit Edison Purchase Order No. 1-A85043 (see Ref. 2), the valve impact velocities for run SD-A were overpredicted by a factor of more than 2, as can be seen from the scatter plot in Figure 2.

The scatter plots in Figures 2 and 3 were generated by considering the 28 chugs in run SD-A, during which all significant valve actuation took place. These chug periods lasted about ½ second each, and were distributed through 50 seconds of the SD-A run. During many of these chugs, there were a number of seat impacts because the valve bounced. In such cases the maximum impact velocity was used. Thus, each symbol on the scatter plot graphs the maximum predicted impact velocity during a particular chug period against the maximum experimental impact velocity for the same chug. The particular geometric symbol used for a given point shows which ten second time period of run SD-A the corresponding impact was within, as indicated in the plot label. (No correlation between impact velocities and run time was observed.)

It should be noted that the experimental velocities used were derived from measured valve positions by a two point method ($\dot{\theta}_{n+\frac{1}{2}} = |\theta_n - \theta_{n+1}|/\Delta t$) which provides a considerably more conservative and probably also more accurate estimate of impact velocities than a three-point parabolic fit method would.

The parameter study undertaken allowed a value for f to be determined ($f = 2.25$) which minimizes conservatism by making the predictions closer to the experimental velocities, although still conservative. A comparison of the results of the adjusted model with the experimental velocities and the original model is given in Table 1 and Figure 3.

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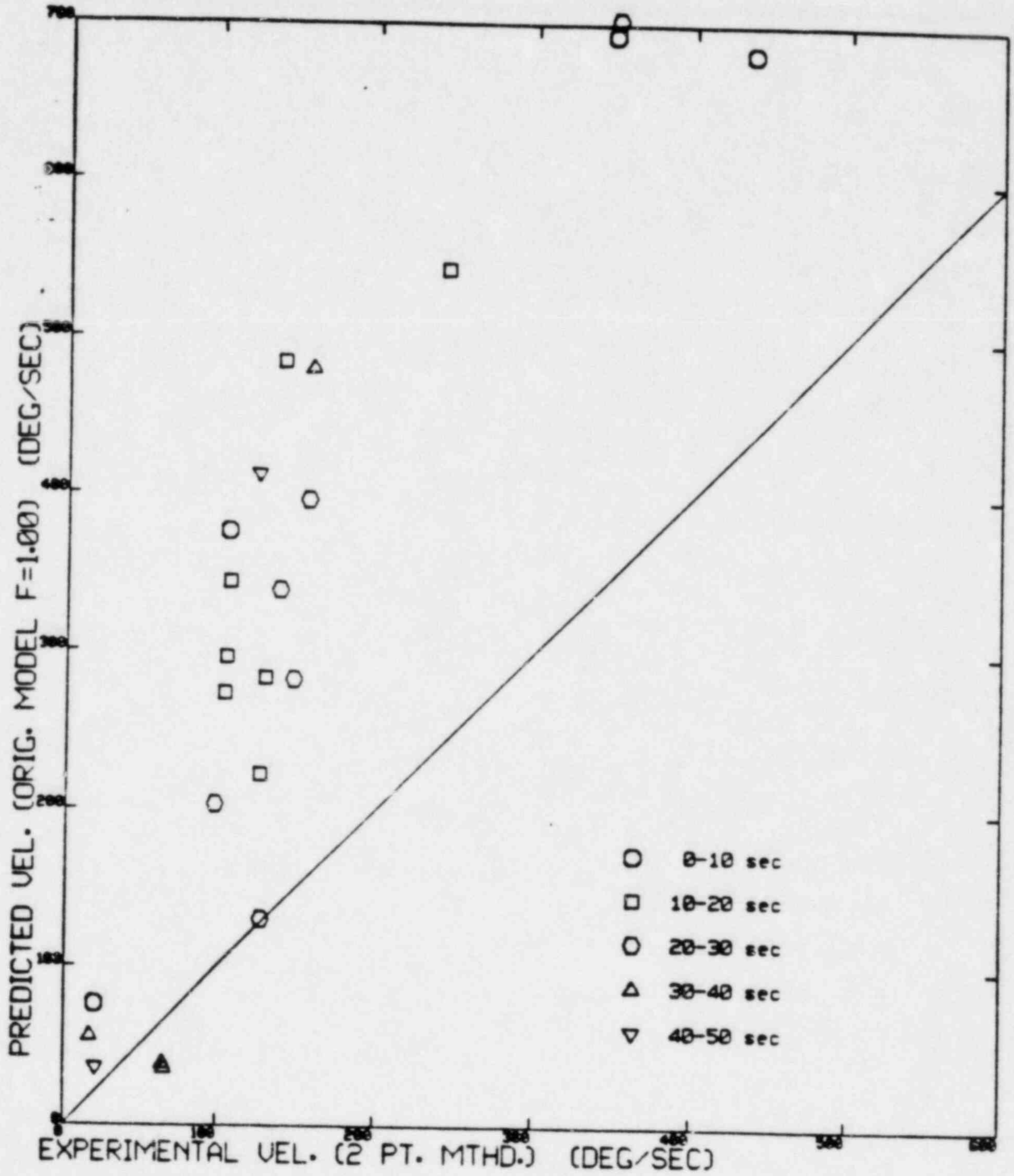

Fugure 2. Comparison of experimental and predicted closing impact velocities for run SD-A ——— original conservative model.

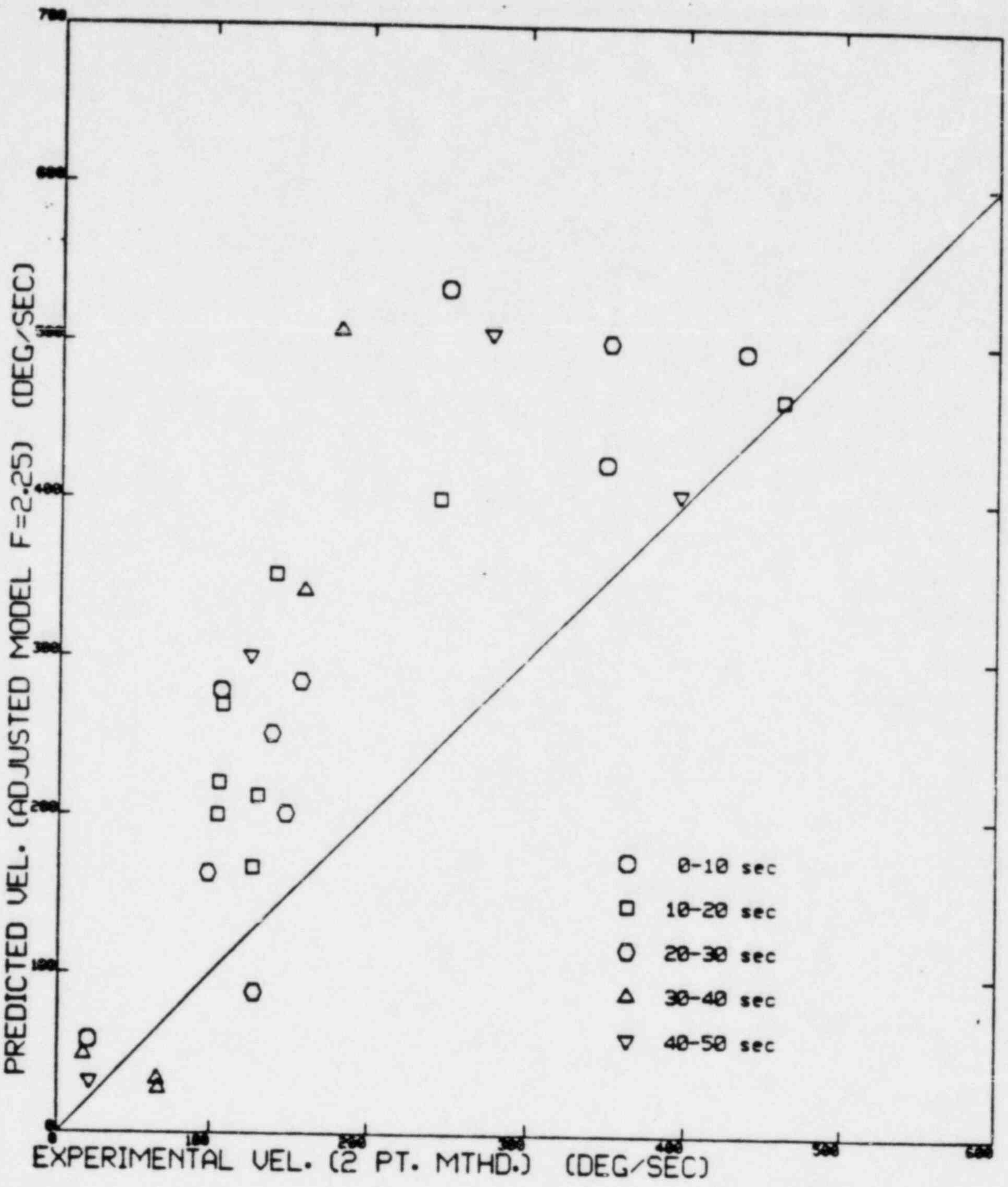

Figure 3. Comparison of experimental and predicted closing impact velocities for run SD-A ——— adjusted model with minimized conservatism.

TABLE 1

GPE Valve Response to SD-A Measured Pressure Signal

	Maximum Seat Impact Velocity (rad/sec)	Number of Impacts above 7.5 rad/sec	Maximum Opening Angle (rad)
Original Model (f = 1.00)	14.35	25	0.73
Adjusted Model (f = 2.25)	9.31	8	0.42
GPE Measured Impact Velocities	8.06	2	0.31

Again, Figure 3 compares the predicted impact velocity for a chug with the experimental impact velocity for the same chug. For example, the square at the right of Figure 3, near the 45° line, shows that, for the chug at 19.1 - 19.8 sec, the predicted velocity was 465 deg/sec, just 1% above the experimental velocity. Similarly, the octagon nearest the top of the plot refers to a chug at 2.9 - 3.7 sec, during which the maximum predicted impact velocity was 533 deg/sec, compared to an experimental velocity of 250 deg/sec. Therefore, for this chug the velocity was 113% overpredicted, and the symbol on the scatter plot is correspondingly high above the 45° line. The average conservatism factor was 1.6

Table 1 on the other hand does not compare impact velocities for the same chug, but instead maxima over the entire run. Thus, the 9.31 rad/sec impact for the adjusted model occurred at 3.5 sec, whereas the 8.06 rad/sec experimental impact occurred at 19.6 sec.

After the model was calibrated, Fermi-2 vacuum breaker response was repredicted from the Mark I, Group 3 chugging differential pressure loading function, shown in Figure 4. This differential pressure history is the ring header pressure for Hope Creek predicted from pressures measured during FSTF run M1 (see Ref. 3) by the Mark I vent model described in References 2 and 3. In this model, condensation source velocities are assumed to be the same for all plants, and the one plant-specific geometric parameter found to affect the predicted forcing function is the drywell volume/vent area ratio. In the Enrico Fermi-2 plant this ratio is 658.06 ft. Under previous work (Ref. 3), Fermi-2 was classified in Group 3 because of the small 2% difference between this figure and the ratio of 642.24 ft for the Hope Creek plant. Sample predictions made of impact velocities showed even smaller differences between Fermi-2 and Group 3.

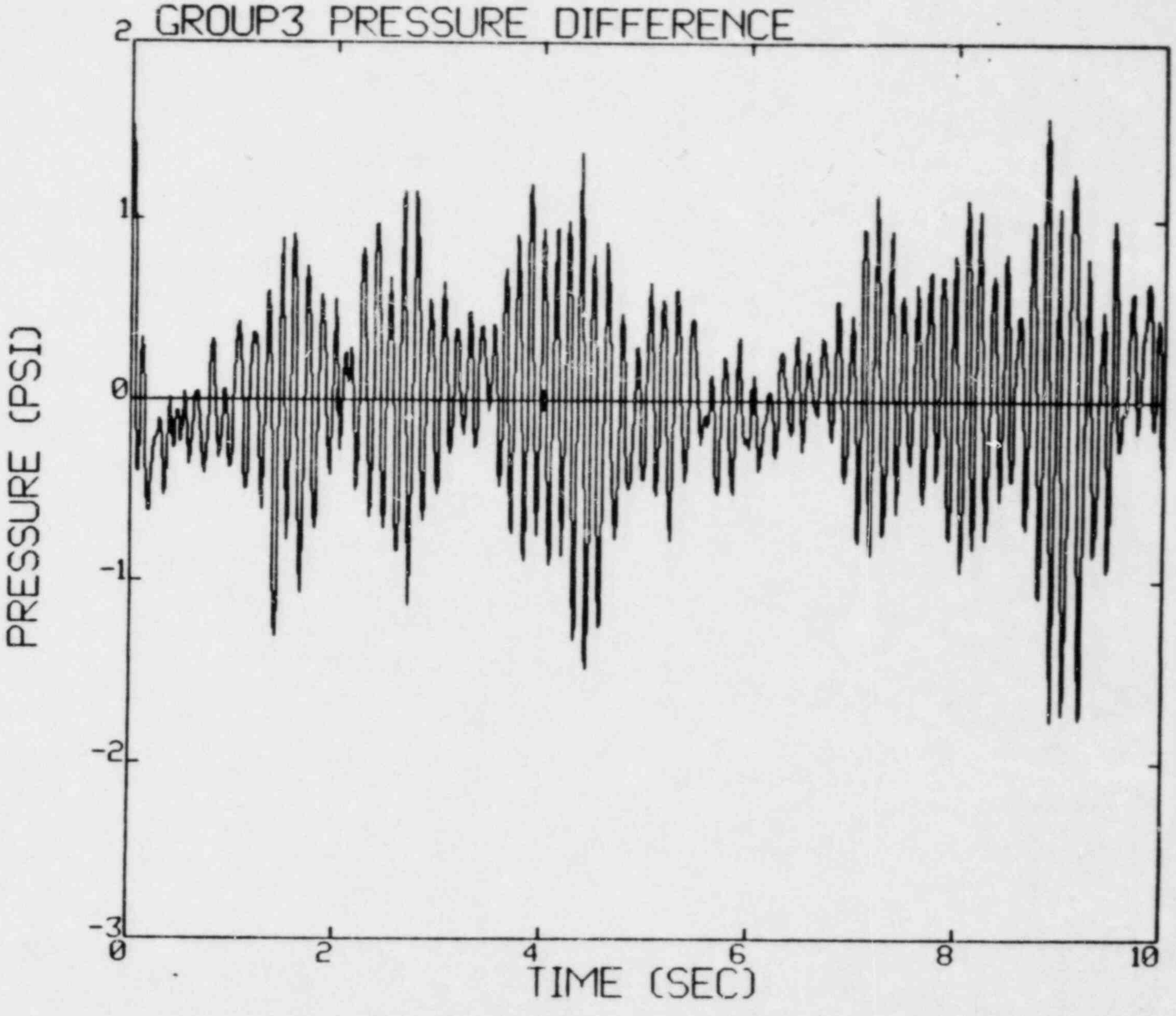

Figure 4. Expected pressure time history across a vacuum breaker located on the ring header for Group 3. The submergence head has not been added to this plot. a. First ten seconds.

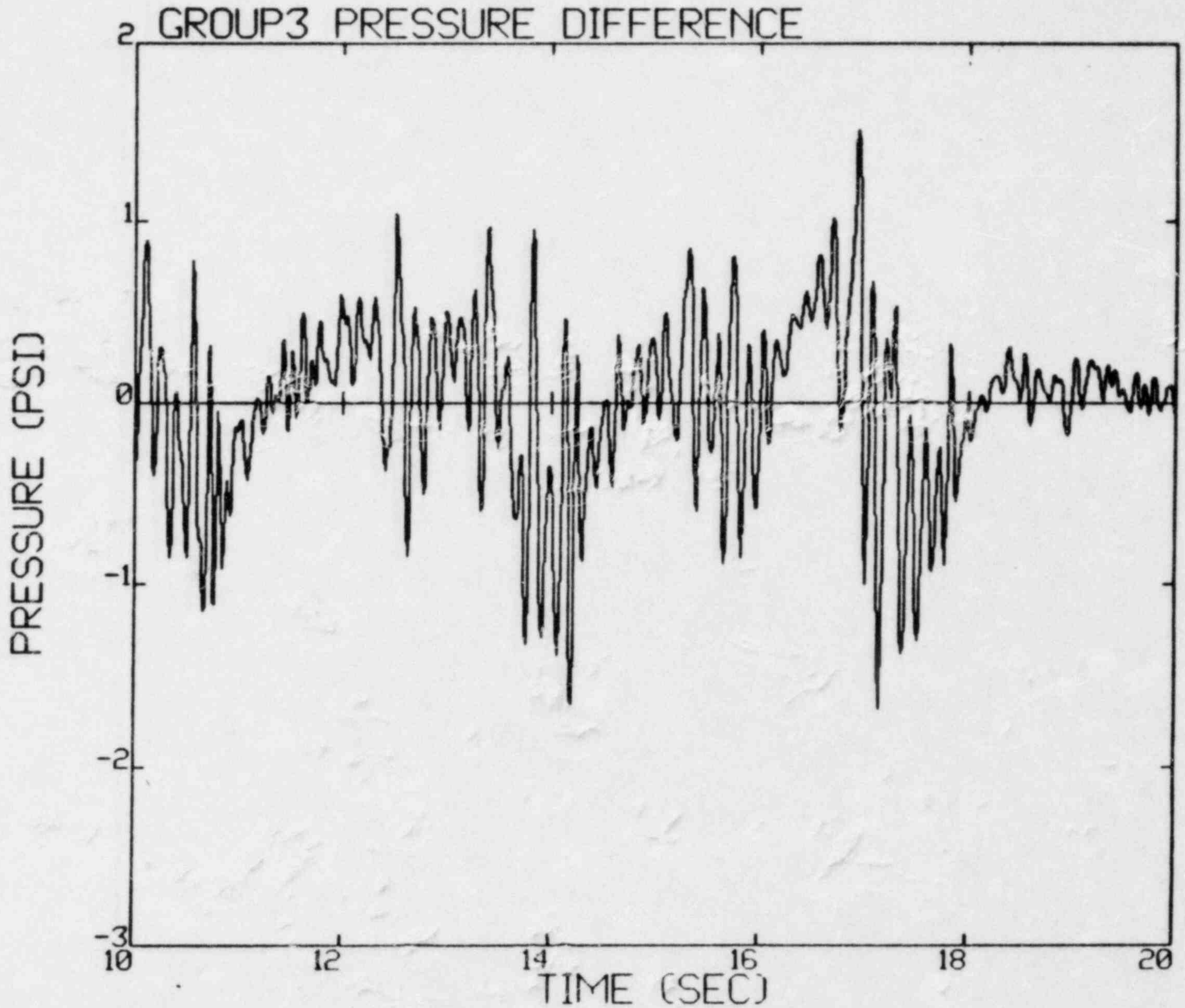

Figure 4b. Second ten seconds.

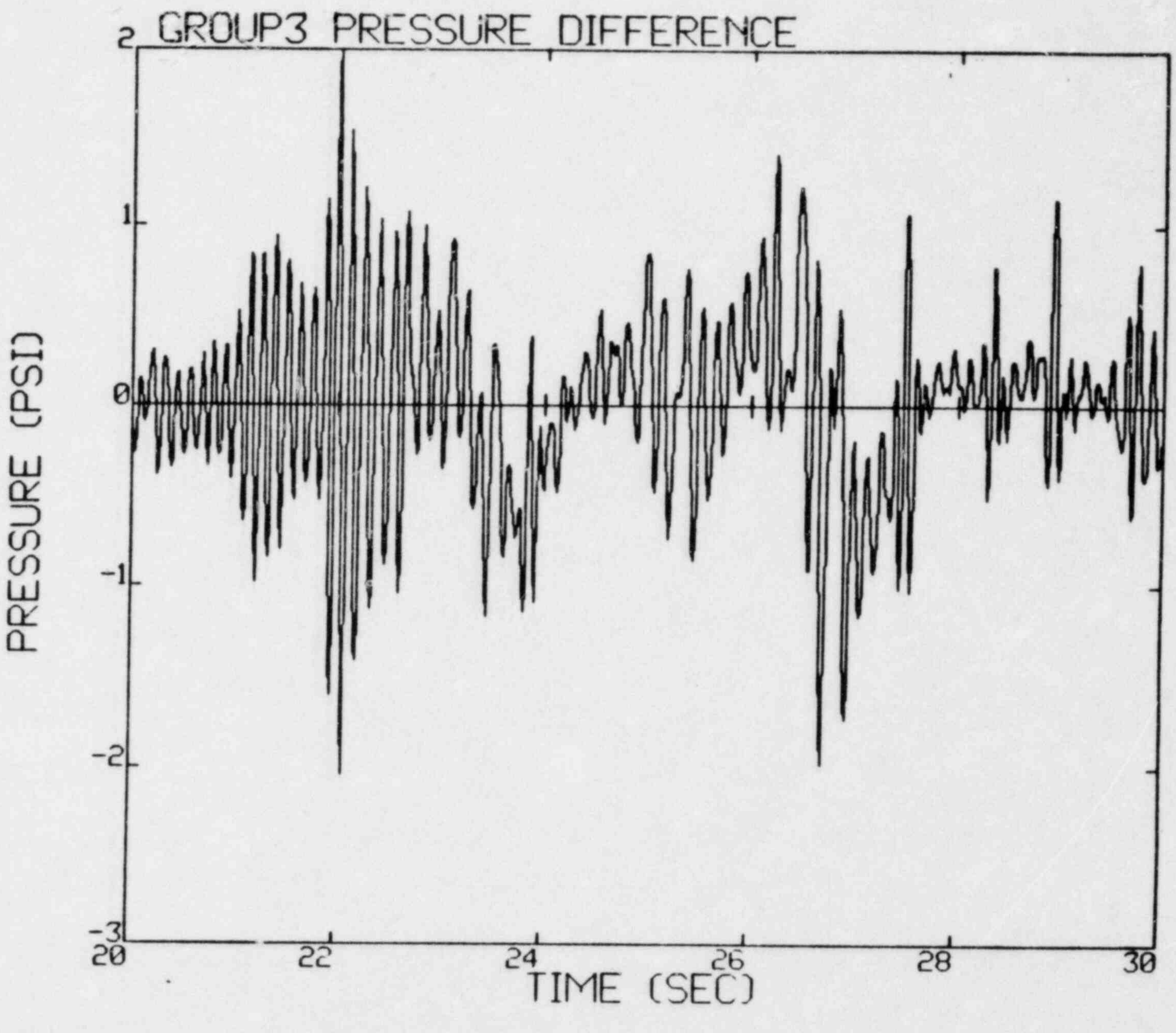

Figure 4c. Third ten seconds.

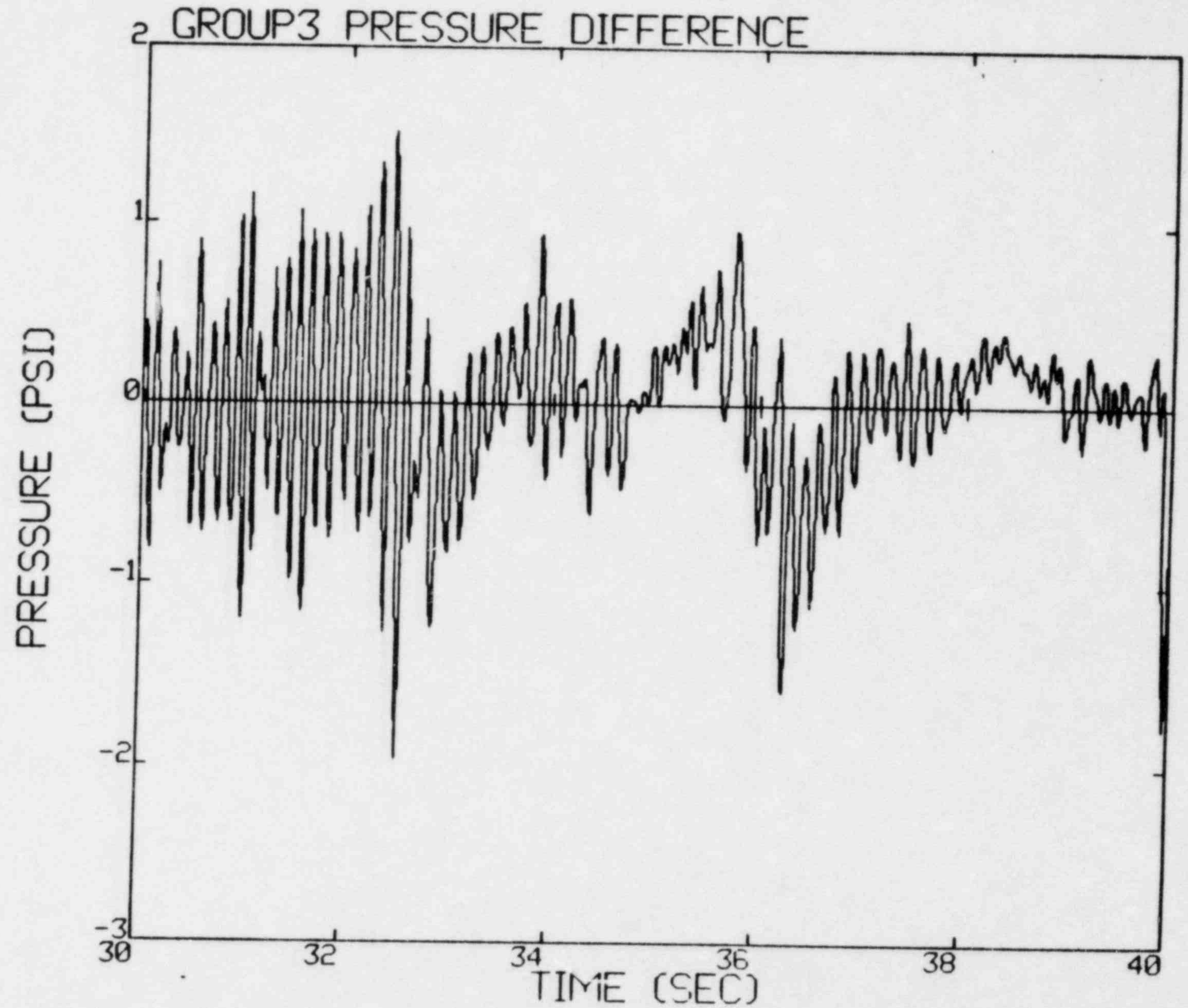

Figure 4d.   Fourth ten seconds.

The GPE 18" internal vacuum breaker characteristics used were those approved by Detroit Edison for the previous work; they are shown in Table 2. The Fermi-2 vacuum breaker response was predicted with the adjusted model (and with the original model parameters for comparison) for both the expected loading function and the design loading function (a factor of safety of 1.6 applied to the predicted pressure). Table 3 shows the maximum impact velocities, number of impacts and maximum opening angle for these cases. The model calibration has reduced these figures by 30% to 40%, so that the expected impact velocities are all below 4 rad/sec. A graph of the expected valve velocity for Fermi-2 is shown in Figure 5.

TABLE 2

Vacuum Breaker Characteristics for Fermi-2

Vacuum breaker type	GPE 18" Internal
System moment of inertia ($lb\text{-}in\text{-}s^2$)	20.38
System moment arm (in)	10.71
Disc moment arm (in)	11.47
System weight (lb)	50.9
Disc area (in^2)	375.82
System rest angle (rad)	0.0
Seat angle (rad)	0.0
Body angle (rad)	1.32
Seat coefficient restitution	0.6
Body coefficient restitution	0.6

TABLE 3

Vacuum Breaker Valve Response in Fermi-2

	Maximum Impact Velocity (rad/sec)	Number of Impacts(2)	Maximum Opening Angle (rad)(3)
Expected Loading Function(1) (Factor of safety = 1.0)			
Original model (f = 1.00)	5.6	18	0.06
Adjusted model (f = 2.25)	4.0	12	0.04
Design Loading Function(1)			
Original model (f = 1.00)	10.8	36	0.15
Adjusted model (f = 2.25)	7.6	30	0.11

(1) Submergence head is taken as 1.3 psi. Vacuum breaker assumed to be mounted at the main vent/ring header junction. Mark I, Group 3 pressure driving force time history was used.

(2) Seat impacts above 1 rad/sec.

(3) Body impacts do not occur.

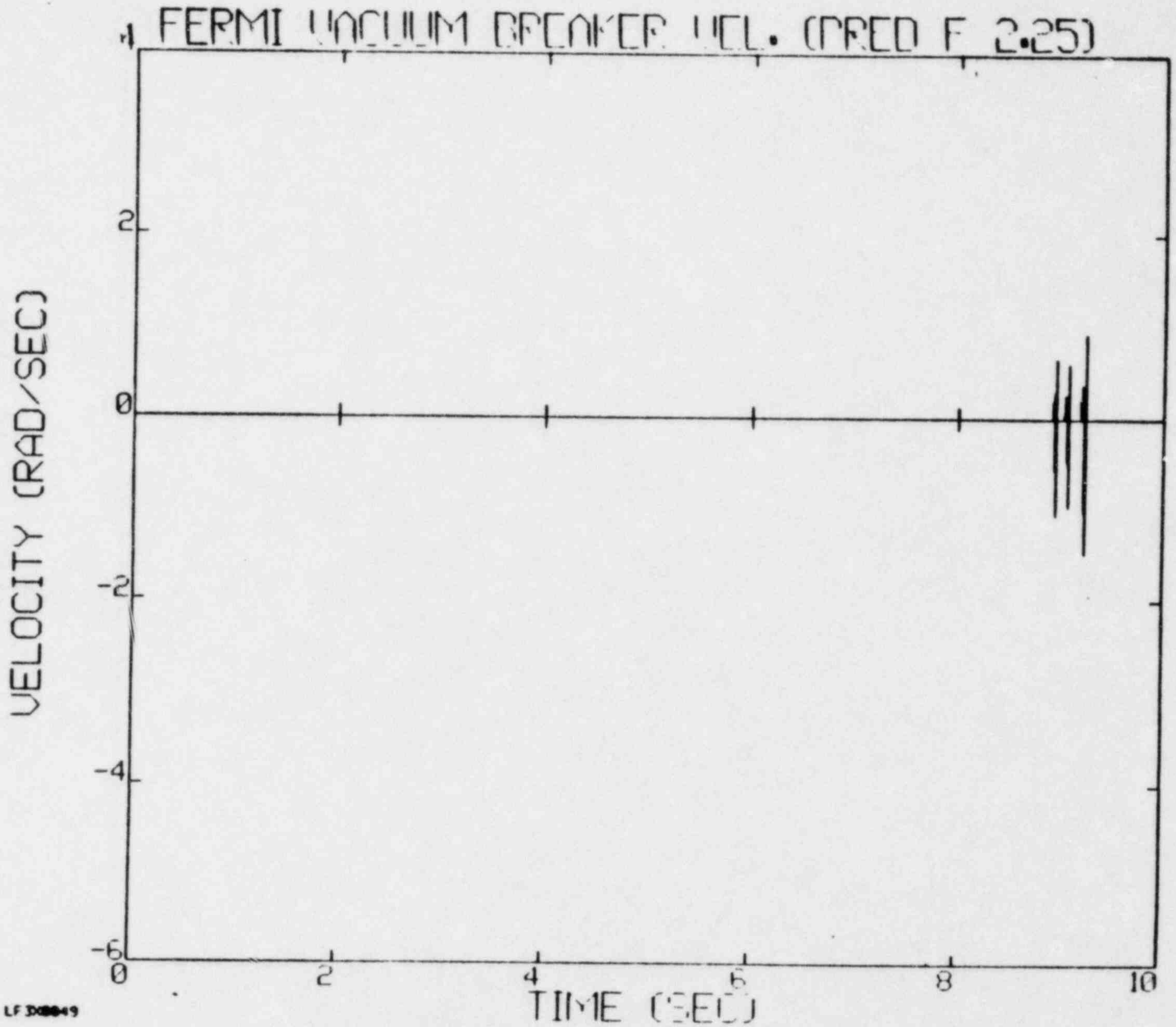

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Figure 5. Vacuum breaker angular velocity response to the expected loading function displayed in Figure 4 predicted with the adjusted model with minimized conservatism. a. First ten seconds.

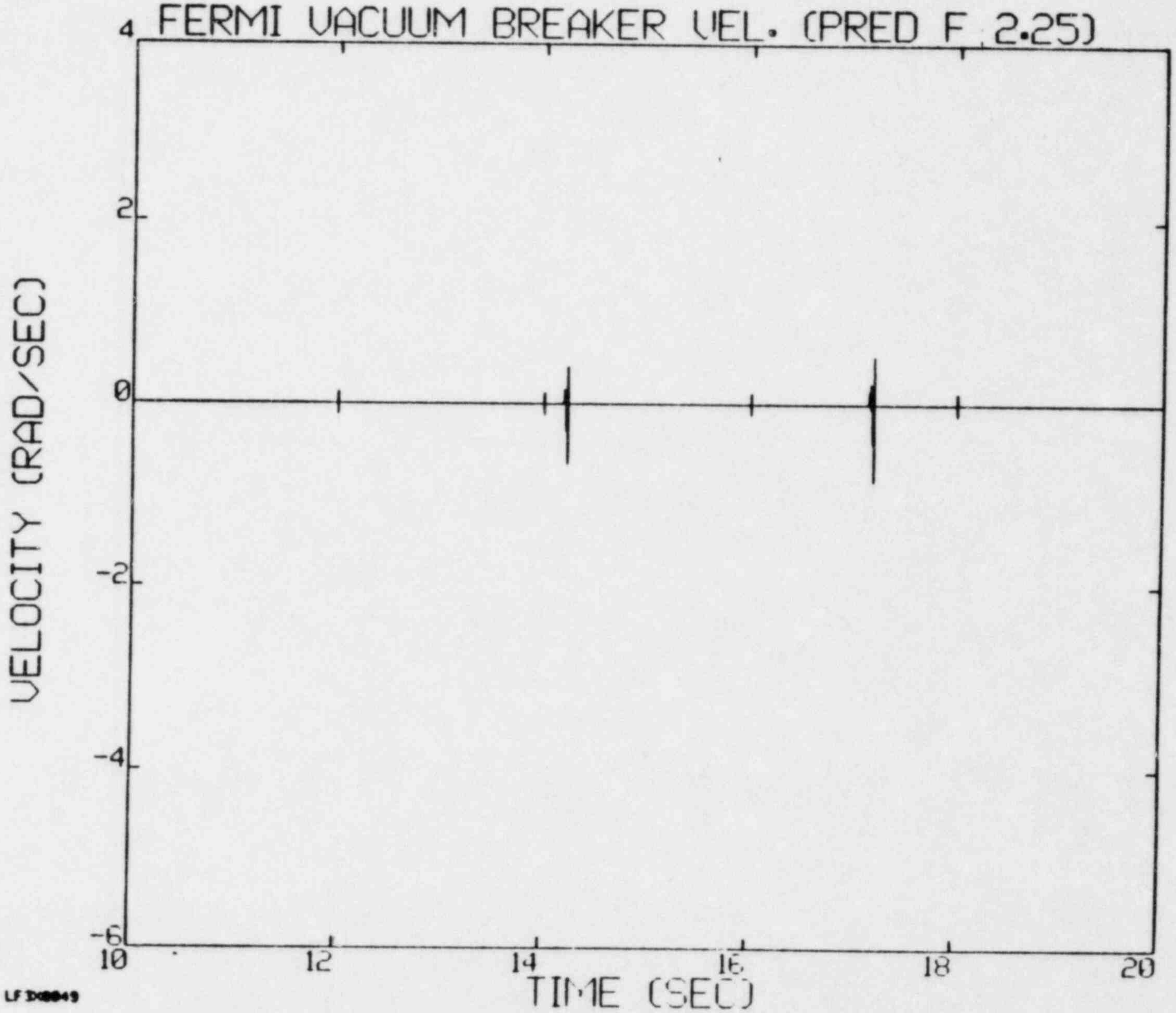

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Figure 5b. Second ten seconds

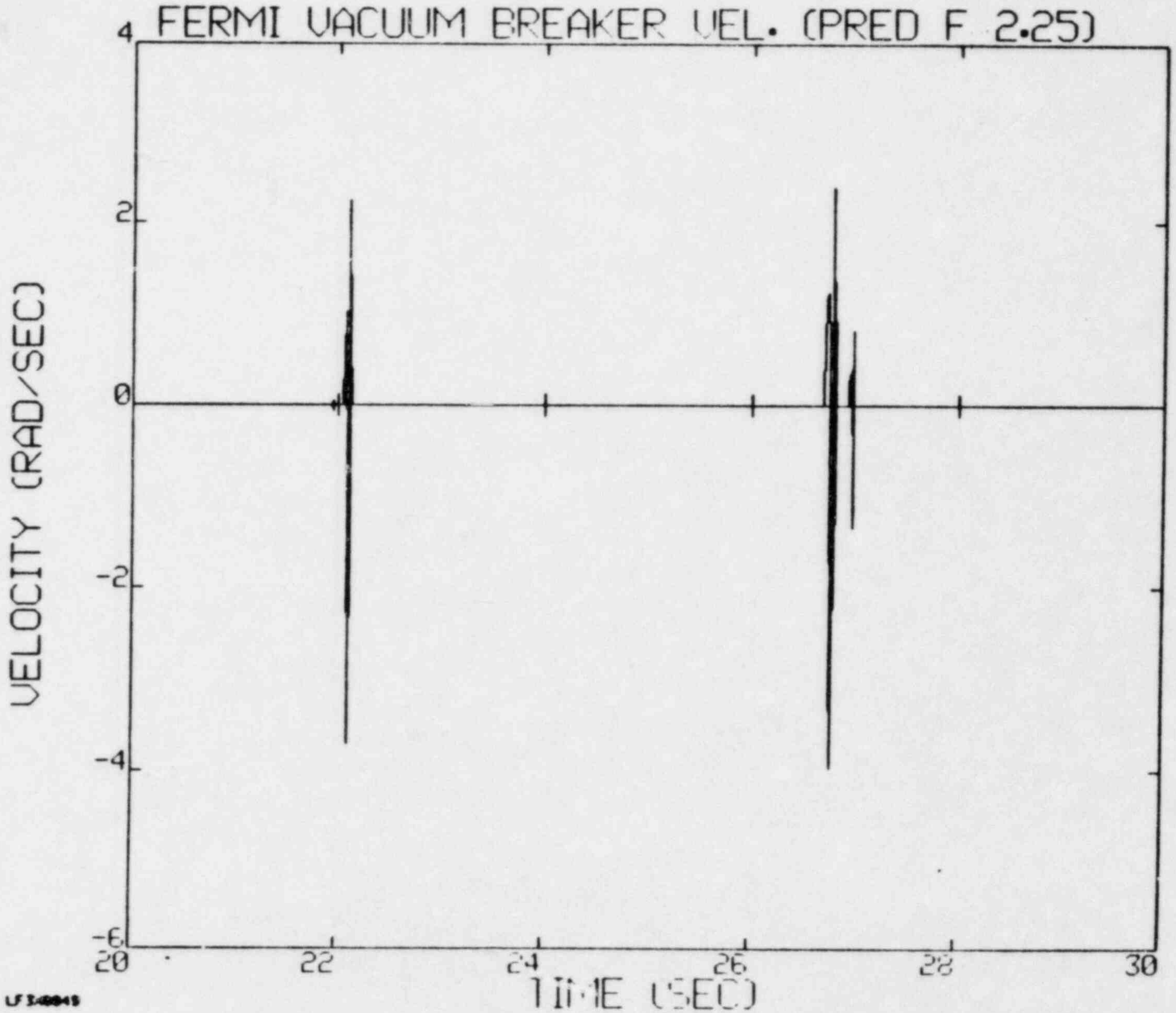

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Figure 5c. Third ten seconds.

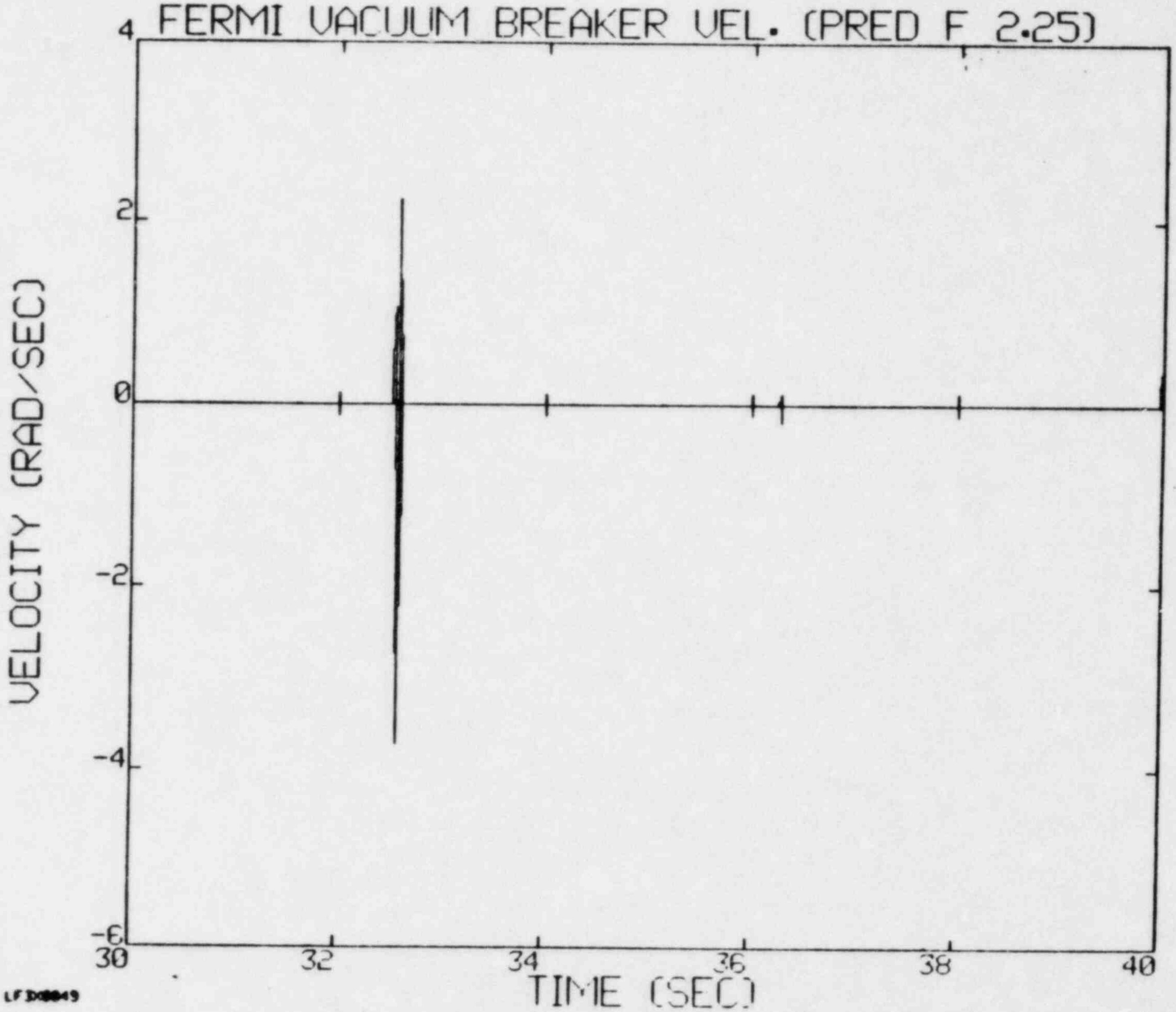

Figure 5d. Fourth ten seconds.

REFERENCES

1. "Mark I Vacuum Breaker Improved Valve Dynamic Model - Model Development and Validation," C.D.I. Tech. Note No. 82-31, August 1982.

2. "Dynamic Vacuum Breaker Forcing Function and Vacuum Breaker Valve Response for Fermi-2," C.D.I. Tech. Note No. 81-18, January 1982.

3. "Mark I Vacuum Breaker Dynamic Load Specification," C.D.I. Report No. 80-4, February 1980.