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REANALYSIS OF THE LASALLE WETWELL TO DRYWELL VACUUM BREAKERS UNDER POOL SWELL LOADING CONDITIONS

First Draft

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SUMMARY

Studies sponsored by the Mark II Owners' Group have predicted that the LaSalle wetwell to drywell vacuum breakers will cycle during the pool swell transient. During this transient, the valve disc is predicted to impact the opening stop at 28.2 rad/sec and reseat with an impact velocity of 30.3 rad/sec. Reducing the conservatism in the valve dynamic model used to make the above predictions, as well as taking credit for the pressure drop across the external piping and butterfly isolation valves, results in predicted opening and closing impact velocities of 18.5 rad/sec and 25.5 rad/sec, respectively.

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1. INTRODUCTION

Mark II wetwell to drywell vacuum breakers are expected to cycle under the pool swell differential pressure time history loads. These loads were specified by the General Electric Company and were transmitted to the NRC on July 23, 1982 (Ref. 1). To estimate the valve disc actuation velocities to be anticipated, the Mark II Owners' Group supported the development of a vacuum breaker valve dynamic model. This model is documented in Reference 2 and has been used to predict the actuation velocities to be anticipated during pool swell for all domestic Mark II plants.

The predictions of impact velocity during pool swell transient for LaSalle are very conservative for two reasons:

a) The hydrodynamic torque generated on the valve disc as a consequence of the pool swell differential pressure upstream and downstream of the valve very conservatively bounds full scale test data.

b) The pool swell differential pressure loading was applied across the LaSalle vacuum breaker without taking credit for the reduction of this differential loading resulting from pressure losses associated with the external piping and isolation valves which connect the vacuum breaker between the wetwell and drywell.

Commonwealth Edison Company, realizing that their current wetwell to drywell vacuum breaker pool swell impact loads were very conservative, initiated an effort to predict more realistic yet conservative impact velocities. The remainder of this report outlines the valve modeling improvements which have been made and documents the reduction of the valve disc impact velocities during pool swell which are achieved when a more realistic estimate of hydrodynamic torque on the valve disc is implemented in the valve dynamic model and credit is taken for losses associated with vacuum breaker piping.

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2. ANALYSIS

2.1 Reduction of Conservatism in the Hydrodynamic Torque as a Function of Valve Opening Angle.

A schematic of a wetwell to drywell vacuum breaker is shown in Figure 2.1. It was shown in Reference 2 that, with regard to the detailed unsteady flow field about the vacuum breaker disc, fluid velocities were sufficiently high such that the fluid mechanics could be treated as quasi-steady. This simplification greatly reduced the effort in developing a valve dynamic model by allowing the hydrodynamic torque to be measured at the disc shaft as a function of valve opening angle and measured differential pressure across the valve disc. These tests were undertaken at the Anderson, Greenwood & Company Test Facility in El Campo, Texas, and the results are summarized in Figure 2.2 where the hydrodynamic torque is defined as

$$\tau_H = \Delta p L_D A_D g(\theta)$$

The quantity $g(\theta)$ is a valve dependent function which accounts for the reduction of hydrodynamic torque with valve opening angle. The dashed curve denoted as "design basis" conservatively bounds the data and has been used in the initial prediction of valve disc impact velocity to pool swell. It is shown in Figure 2.3 that if the solid curve is implemented into the model the predictions of disc impact velocity are conservative when compared against test data. The solid hydrodynamic torque relations will be utilized to repredict LaSalle's pool swell disc impact velocities.

2.2 Reduction of the Pool Swell Differential Pressure Loading Across the Vacuum Breaker Resulting from Piping and Isolation Valve Losses.

The LaSalle plant is unique in that it is the only domestic Mark II plant which has its vacuum breakers located outside containment. A sketch of a typical (there are four lines) vacuum breaker piping is shown in Figure 2.4. Previous analysis of vacuum breaker dynamics applied the differential pressure resulting from pool swell across the vacuum breaker at Stations A & B.

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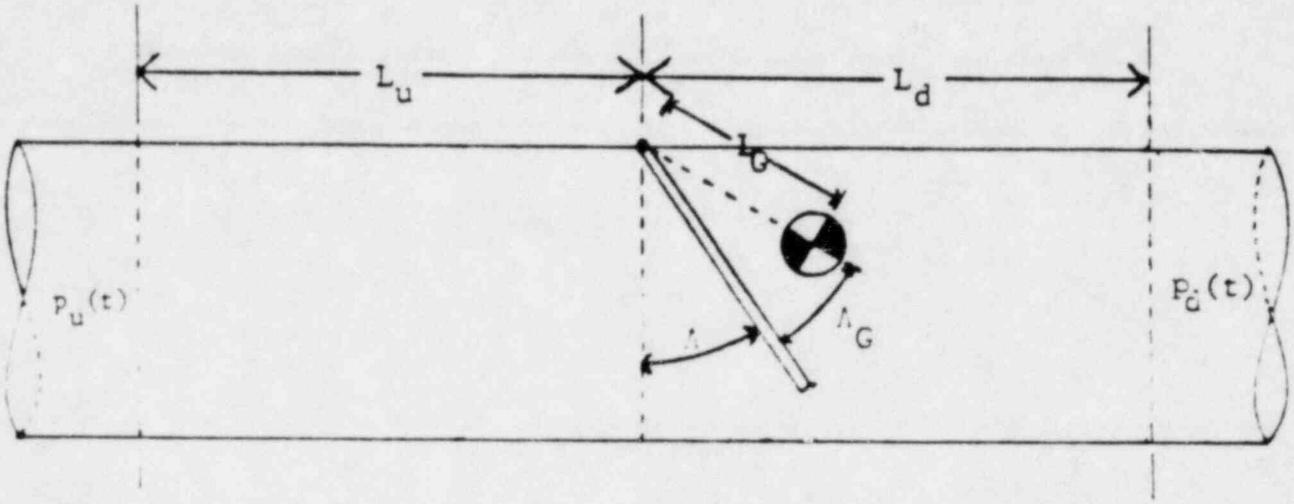

Figure 2.1 Schematic of wetwell to drywell vacuum breaker

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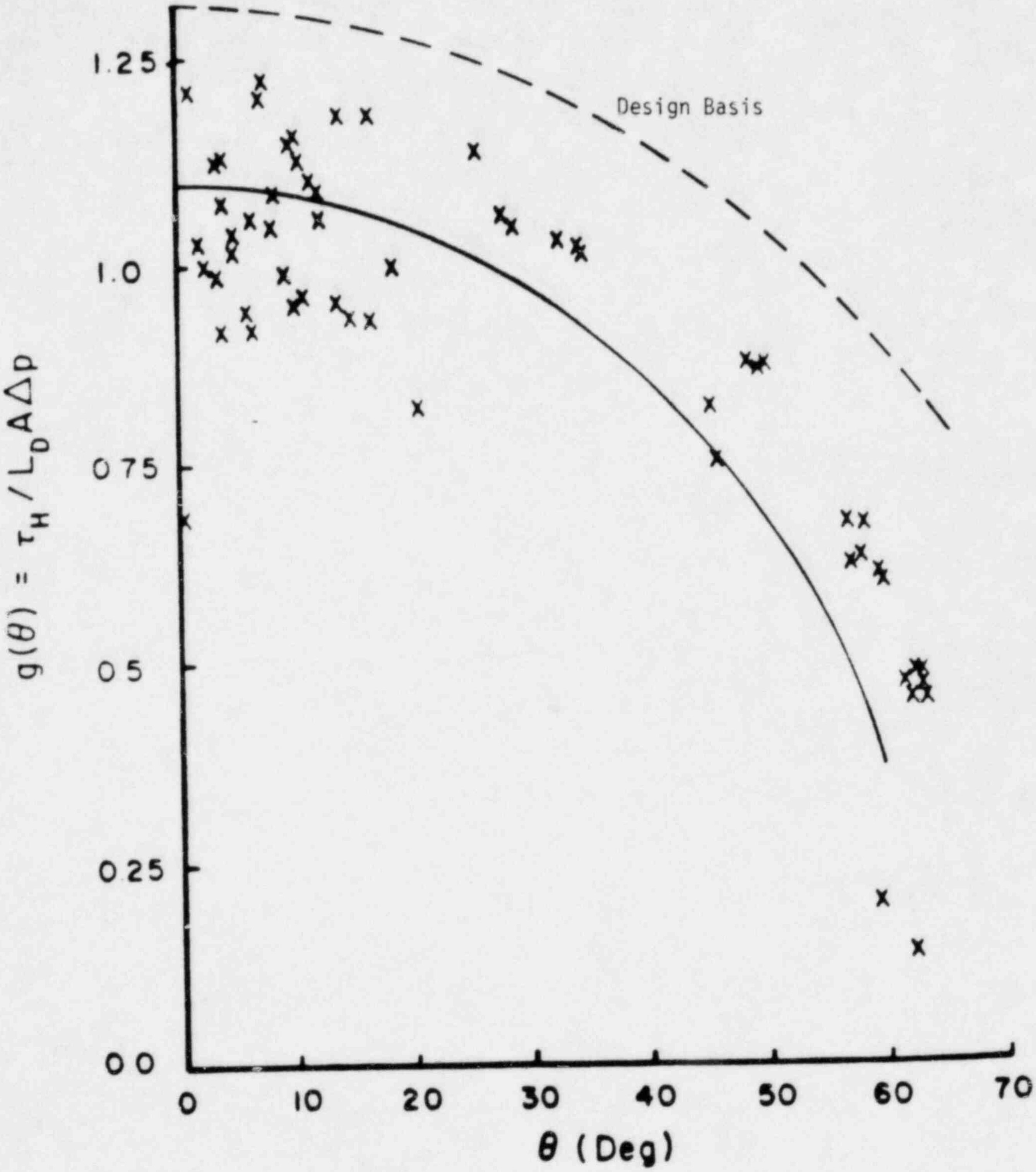

Figure 2.2 Vacuum breaker shaft torque resulting from a differential pressure loading across the valve disc.

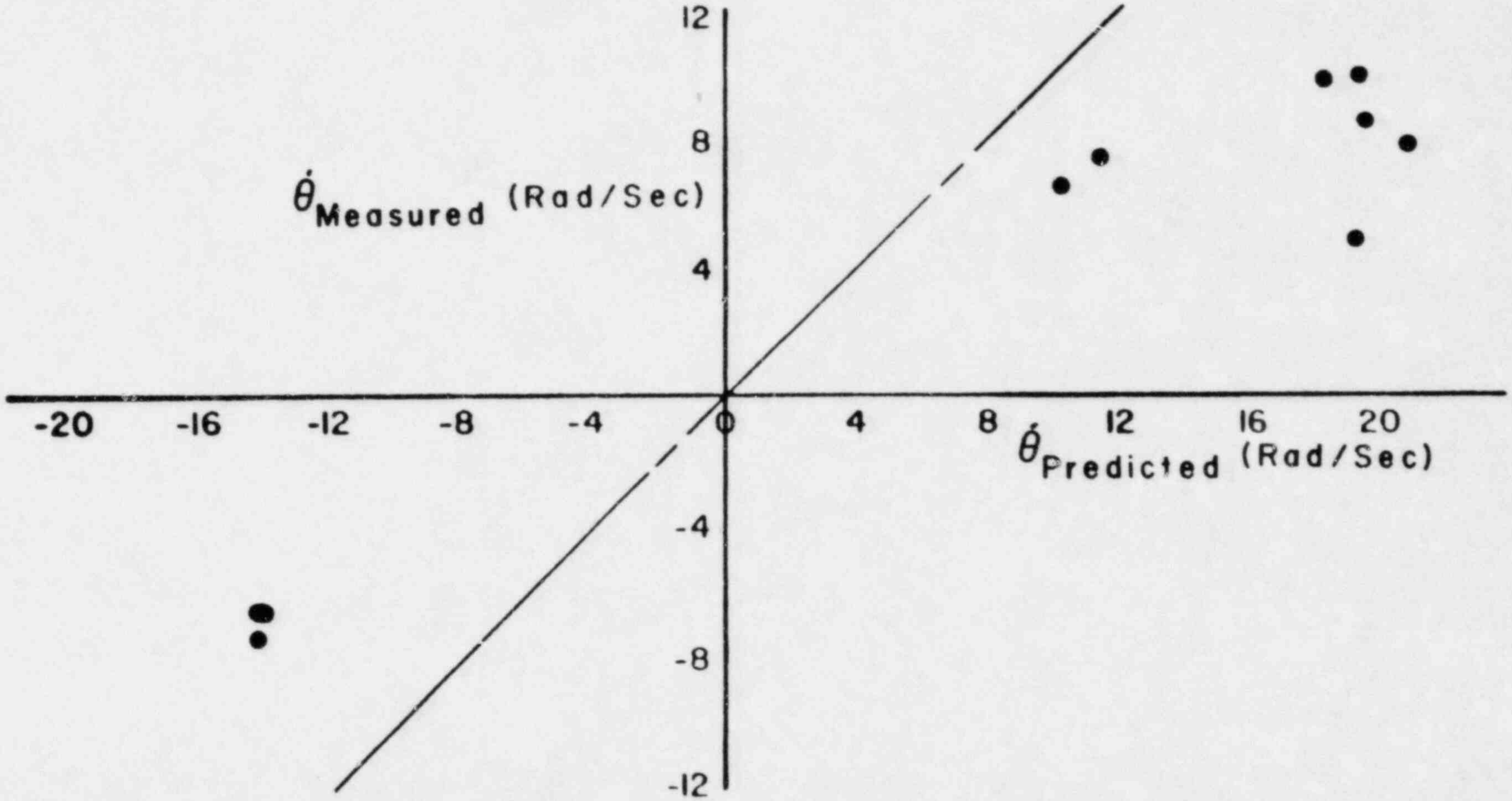

Figure 2.3 Predicted versus measured nominal vacuum breaker disc impact velocities

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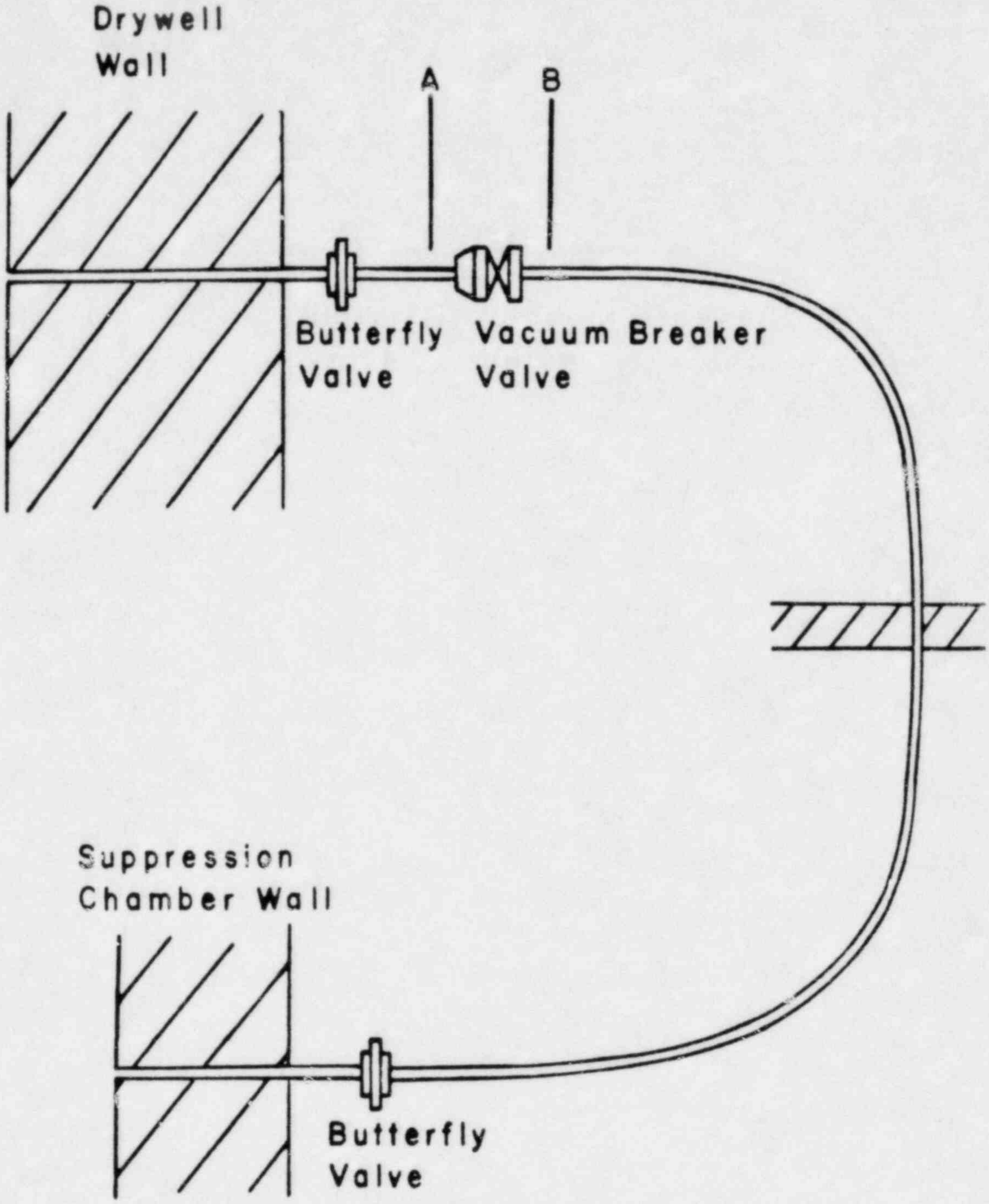

Figure 2.4 Schematic of a typical LaSalle external vacuum breaker

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When credit is taken for the losses associated with the external piping and butterfly valves, it may be shown that the General Electric Company specified vacuum breaker pool swell load can be reduced by

$$\Delta p_{vb} = \Delta p(t) - \tfrac{1}{2}K\rho U|U|$$

where

Δp_{vb} - differential pressure across vacuum breaker disc

$\Delta p(t)$ - General Electric Company specified pool swell load

ρ - gas density

U - velocity of gas in external vacuum breaker line

K - minimum head loss factor for the LaSalle external vacuum breaker line

For the LaSalle external vacuum breaker lines the minimum loss factor has been computed to be 4.5.

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3. RESULTS

The LaSalle vacuum breaker characteristics shown in Table 3.1 have been implemented into the valve dynamics code. One of the eight General Electric Company specified pool swell differential pressure transients is shown in Figure 3.1. The results for disc impact velocities are summarized in Figure 3.2. With no external piping loss, the impact velocity for opening and closing are reduced by 2.7 rad/sec and 1.3 rad/sec, respectively, by replacing the design hydrodynamic torque curve in Figure 2.2 with the solid curve in the valve dynamic model.

The minimum K loss factor for LaSalle's external lines is estimated to be $K = 4.5$. Predicted disc impact velocities for LaSalle are (from Figure 3.2) opening 18.5 rad/sec and closing 25.5 rad/sec. This reduction of impact velocity is associated with a reduction of the differential pressure across the valve disc from head loss. This may be seen by comparing the differential pressure across the valve disc with and without head loss (Figure 3.1 with Figure 3.3).

It is curious that impact velocity is not a strong function of K loss factor. This result can be understood by comparing the volumetric flow rate through the valve with and without losses accounted for. Referring to Figure 3.4 and Figure 3.5, as losses increase, the valve opens more slowly and less mass is passed through the valve. Hence, differential pressure across the valve disc is reduced at a lessening rate since differential pressure across the valve disc is proportional to volumetric flow rate squared.

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TABLE 3.1

LaSalle Valve Characteristics

Parameter Name	Parameter Value
System moment of inertia	34.18 lb/in/sec^2
System weight	57.0 lb
System moment arm	13.84 in.
System angle from rest*	0.0 rad
Seat angle*	0.0 rad
Body angle*	1.047 rad
Disc pallet radius	11.50 in.
Seat coefficient restitution	0.1
Body coefficient restitution	0.1
Magnetic pressure preload	0.5 psi

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* all angles are measured counterclockwise from vertical down.

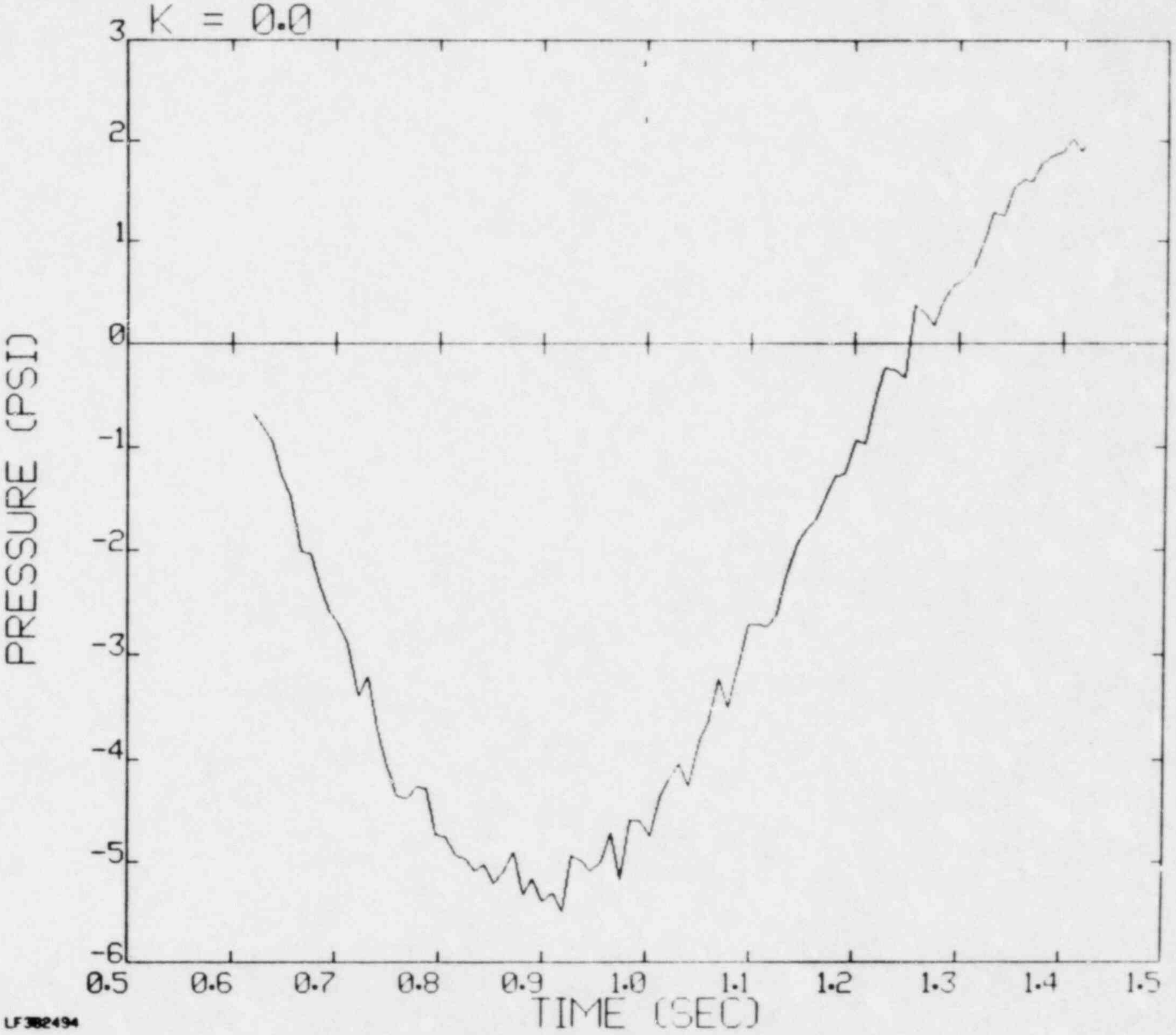

Figure 3.1 Typical General Electric Company specified differential pressure pool swell transient

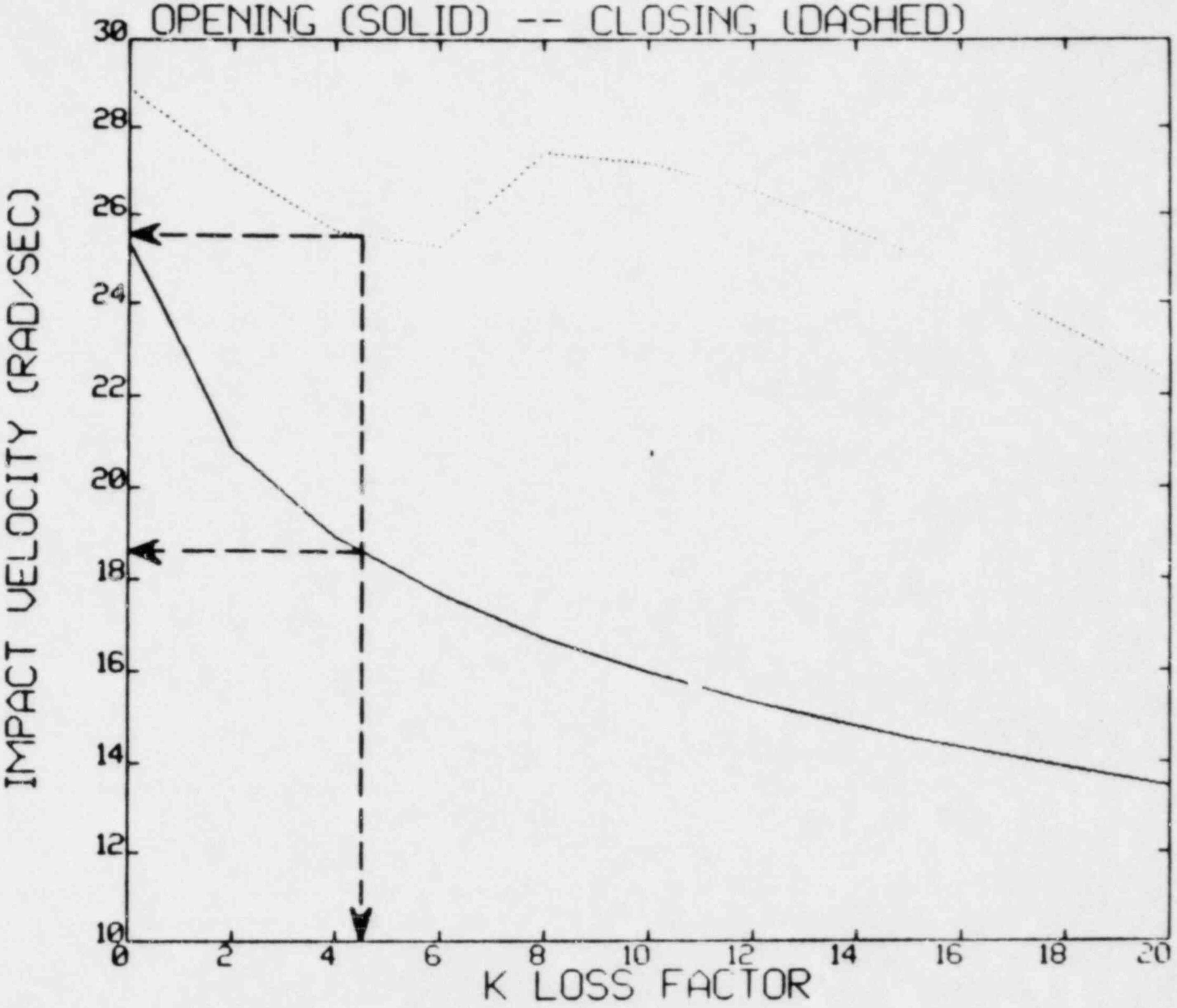

Figure 3.2 Reduction of LaSalle vacuum breaker impact velocity to pool swell resulting from external piping head loss

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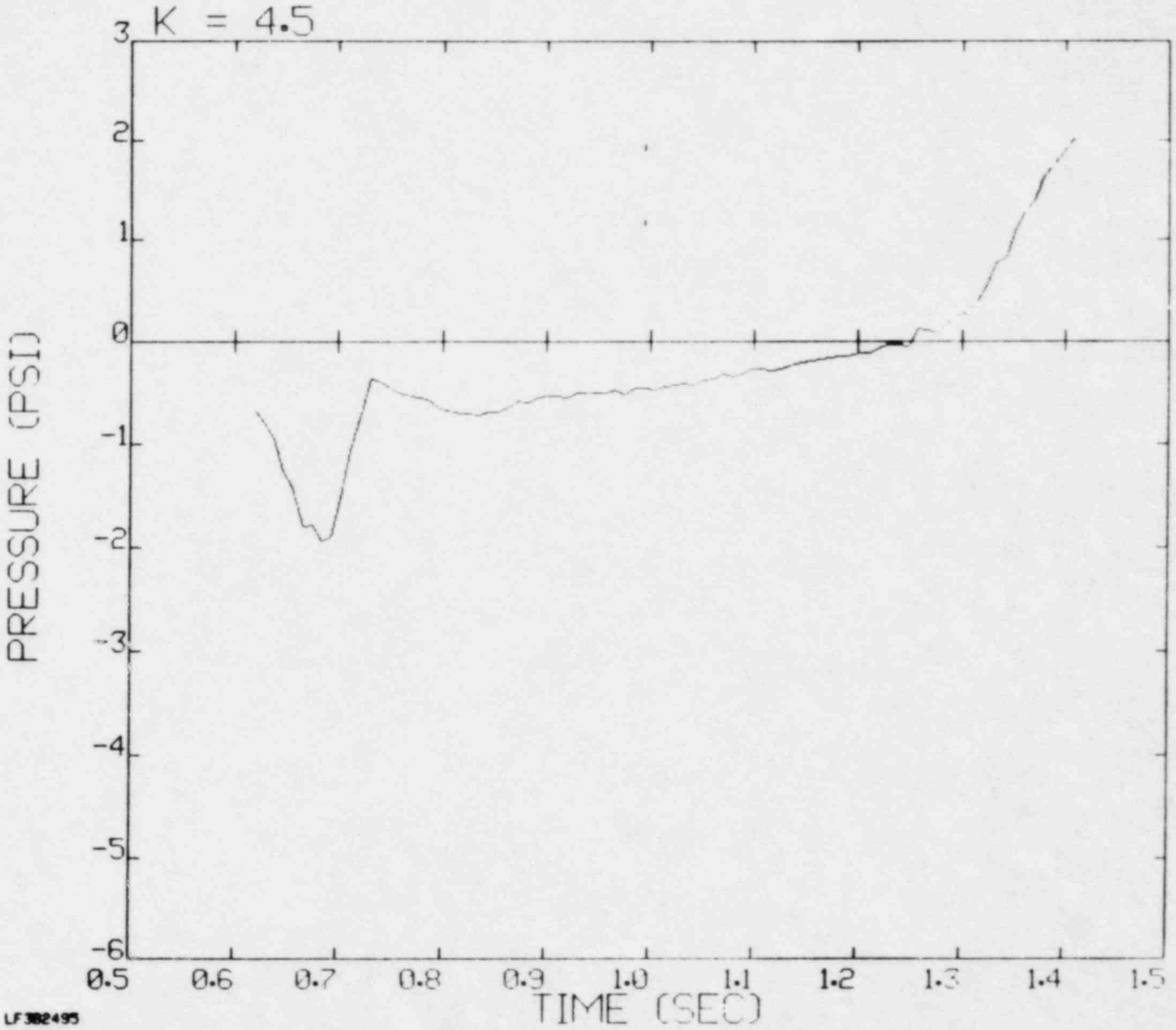

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Figure 3.3 Differential pressure across the LaSalle vacuum breaker disc with head loss equal to 4.5

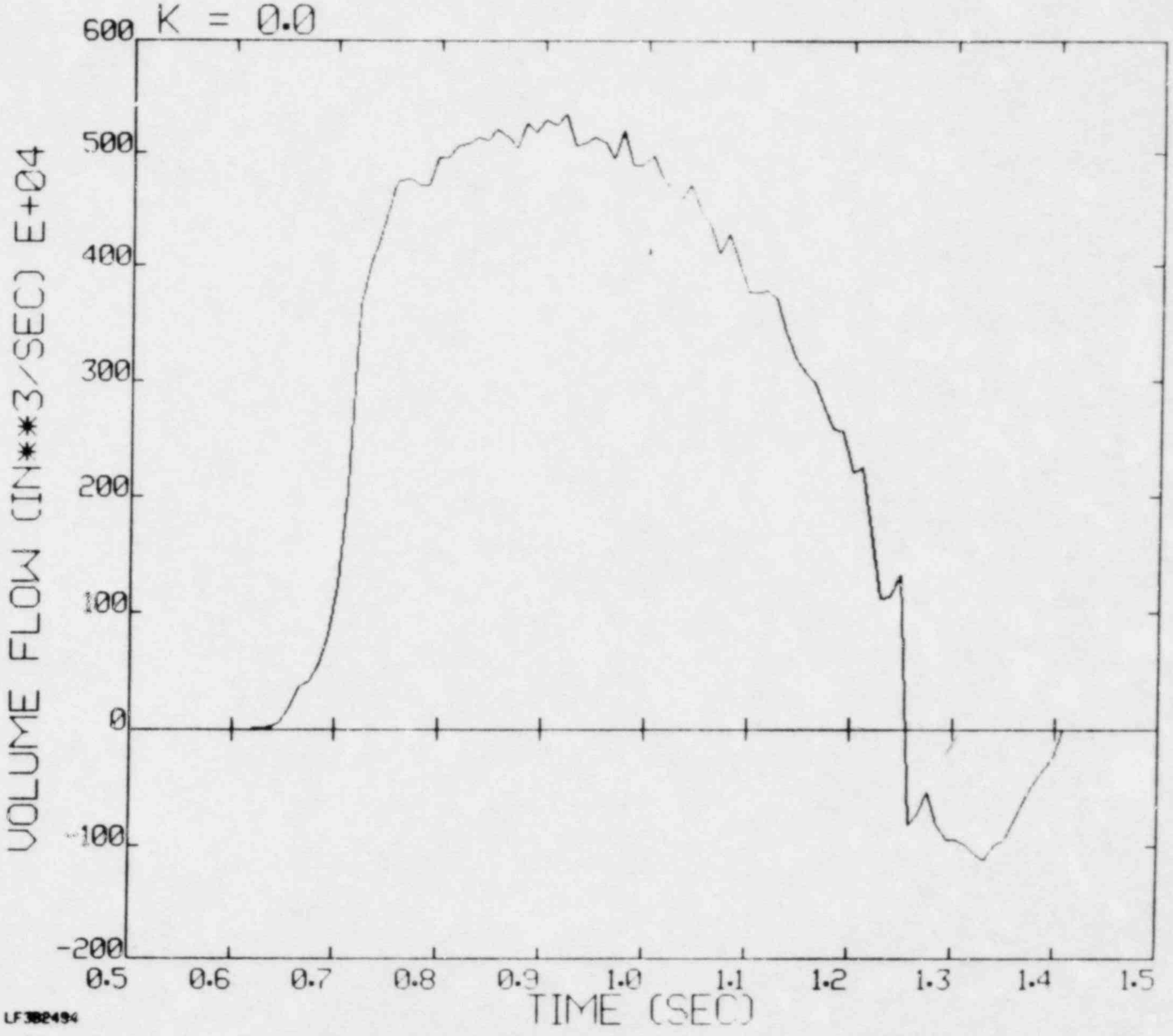

Figure 3.4 Volumetric flow through the vacuum breaker with zero head loss in external piping

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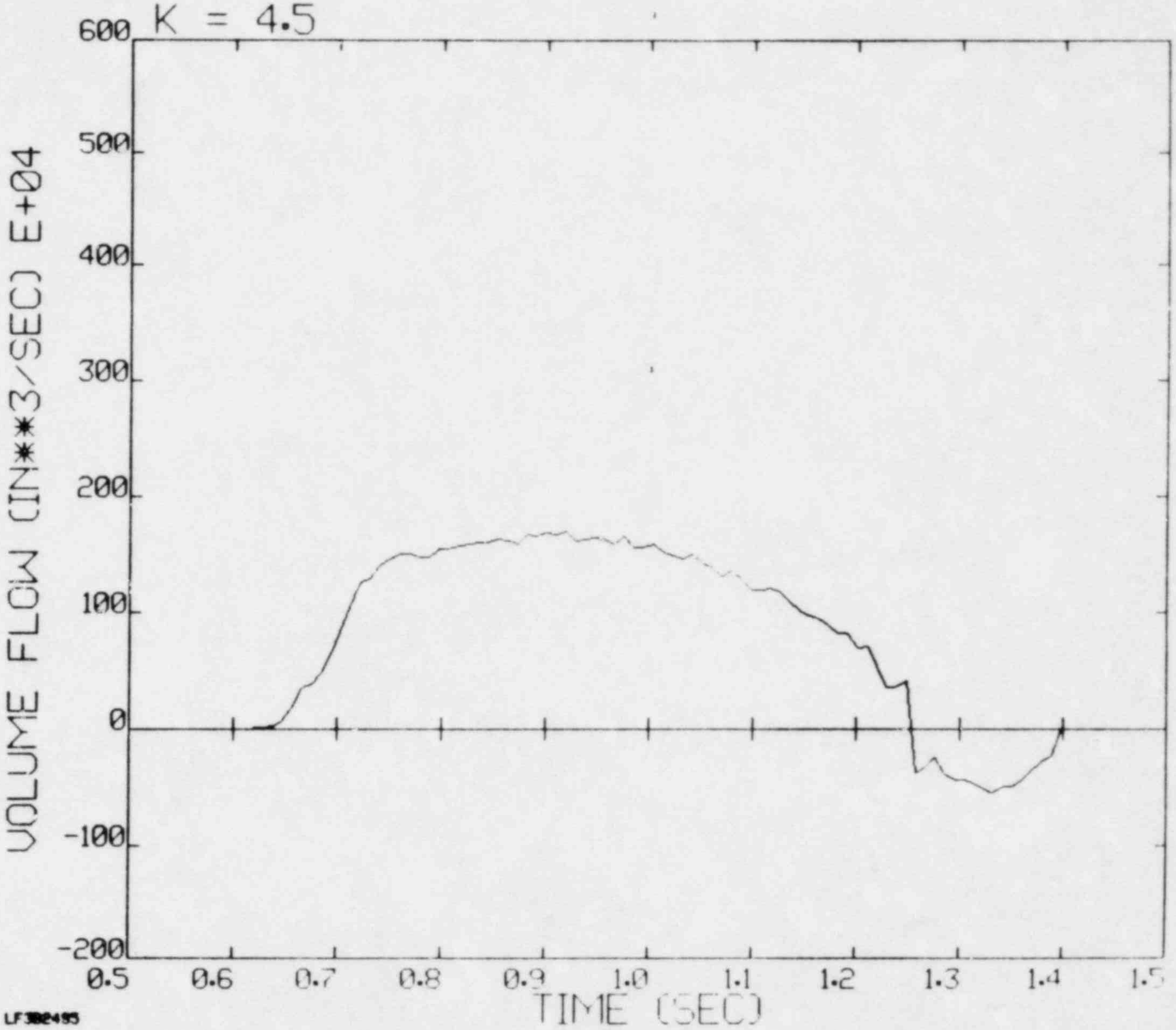

Figure 3.5 Volumetric flow through the vacuum breaker with head loss equal to 4.5 in the external piping

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4. REFERENCES

1. Letter from H.C. Pfefferlen, Manager of BWR Licensing Programs, General Electric Company to T.P. Speis, Assistant Director for Reactor Safety, Nuclear Regulatory Commission. Letter Reference MFN-098-82 dated July 23, 1982.

2. "Mark II Containment Drywell-to-Wetwell Vacuum Breaker Models," General Electric Company Report No. NEDE 22178-P, August 1982.