IMPROVED DYNAMIC VACUUM BREAKER

VALVE RESPONSE

FOR THE BRUNSWICK PLANT

REVISION 1

PREPARED FOR

GENERAL ELECTRIC COMPANY
175 CURTNER AVENUE
SAN JOSE, CALIFORNIA 95125
UNDER PURCHASE ORDER NO. 205-XJ102

BY

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SEPTEMBER, 1982

DISCLAIMER OF RESPONSIBILITY

SUMMARY

Improved plant-unique expected and design vacuum breaker impact velocities have been calculated for the Brunswick plant.

The valve displacement time history was predicted using a valve dynamic model which takes credit for the reduction of hydrodynamic torque across the vacuum breaker as a consequence of valve actuation. Expected vacuum breaker actuation velocities are reduced by 17% over a prediction which does not take credit for hydrodynamic torque reduction.

SUMMARY OF THE METHODOLOGY USED TO DEFINE PLANT-UNIQUE WETWELL TO DRYWELL MARK I VACUUM BREAKER FORCING FUNCTIONS FROM FSTF DATA

During the Mark I FSTF test series, wetwell to drywell vacuum breaker actuation was observed during the chugging phase of steam blowdowns. As a result of this observation, a methodology was developed which can be used to define the loading function acting on a vacuum breaker during chugging (Ref. 1). The methodology developed uses FSTF pressure time history data and adjusts the vent system and wetwell pressures to account for plant-unique geometry. For plants with internal vacuum breakers, the most critical parameter controlling the magnitude of the vacuum breaker forcing function is the drywell volume per vent area. Vacuum breaker forcing functions are specified as a time history of the differential pressure across the valve disc.

The steps taken in the development of the plant-unique forcing function model are shown in Figure 1. Step 1 involves the development of analytic dynamic models for the unsteady motion in the steam vent system (see Figure 2), at the steam water interface (see Figure 3) and in the suppression pool (see Figure 4) assuming that the condensation rate at the steam water interface is known. The dynamics in the vent system are assumed to be governed by one-dimensional acoustic theory and jump conditions across the steam water interface are the Rankine-Hugoniot relations. A one-dimensional model of the suppression pool was developed which accounts for compression of the wetwell airspace

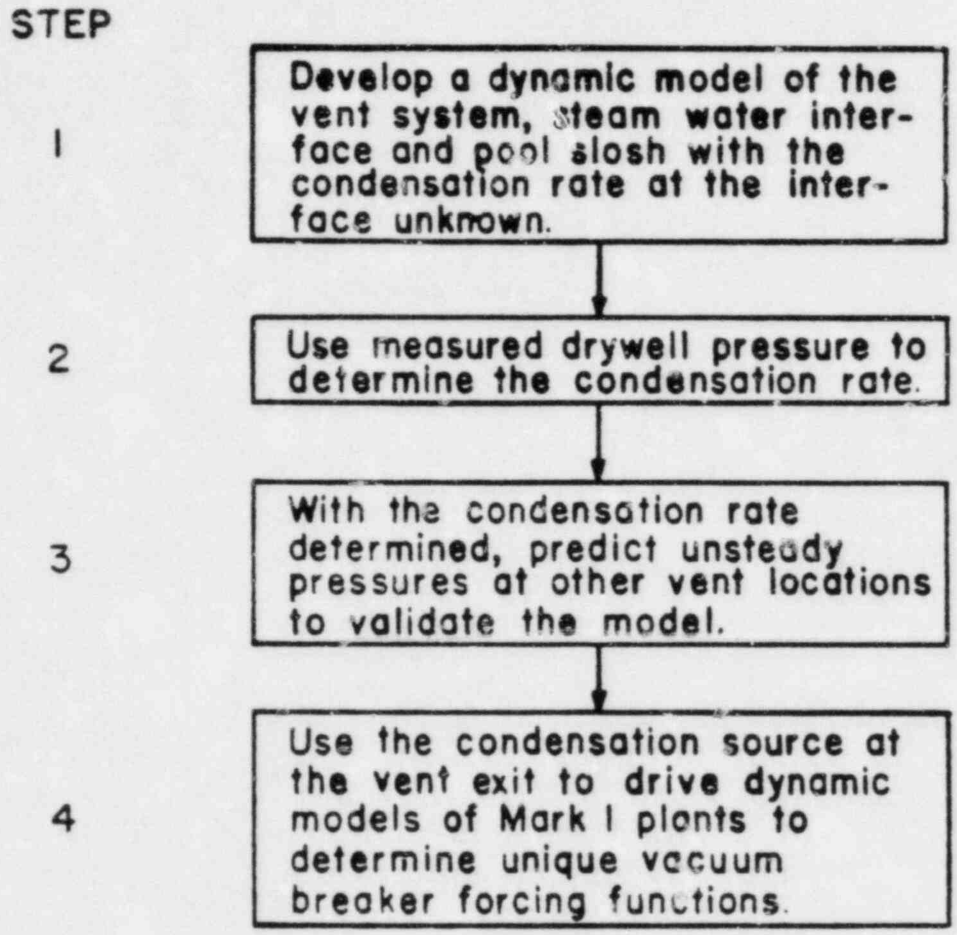

Figure 1. Steps in determining plant unique vacuum breaker forcing functions.

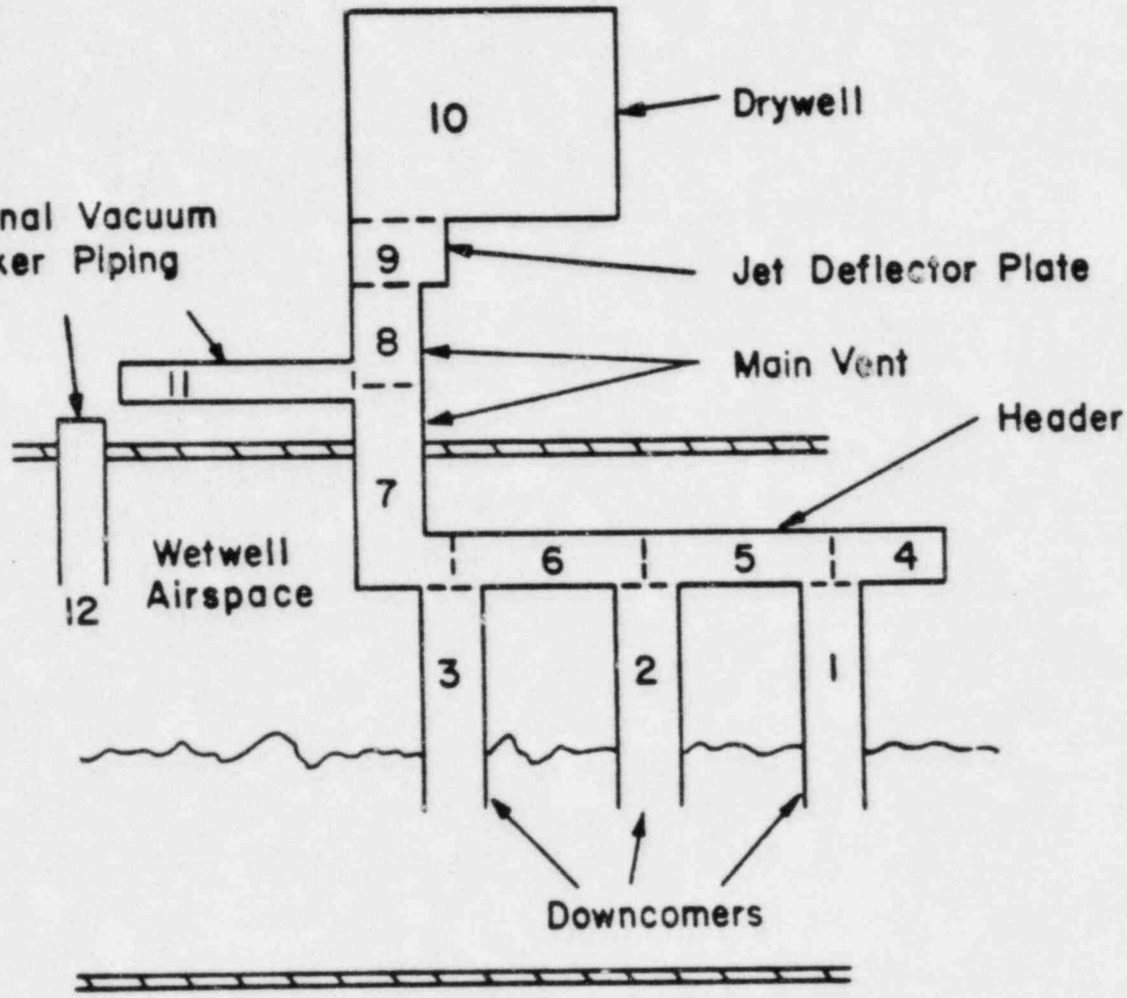

Figure 2. Schematic model of the vent system depicted by 12 dynamic components.

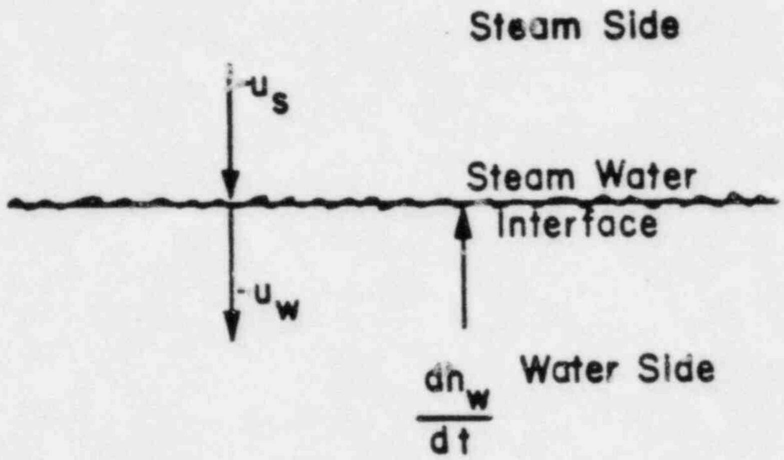

Figure 3. Details of the steam water interface.

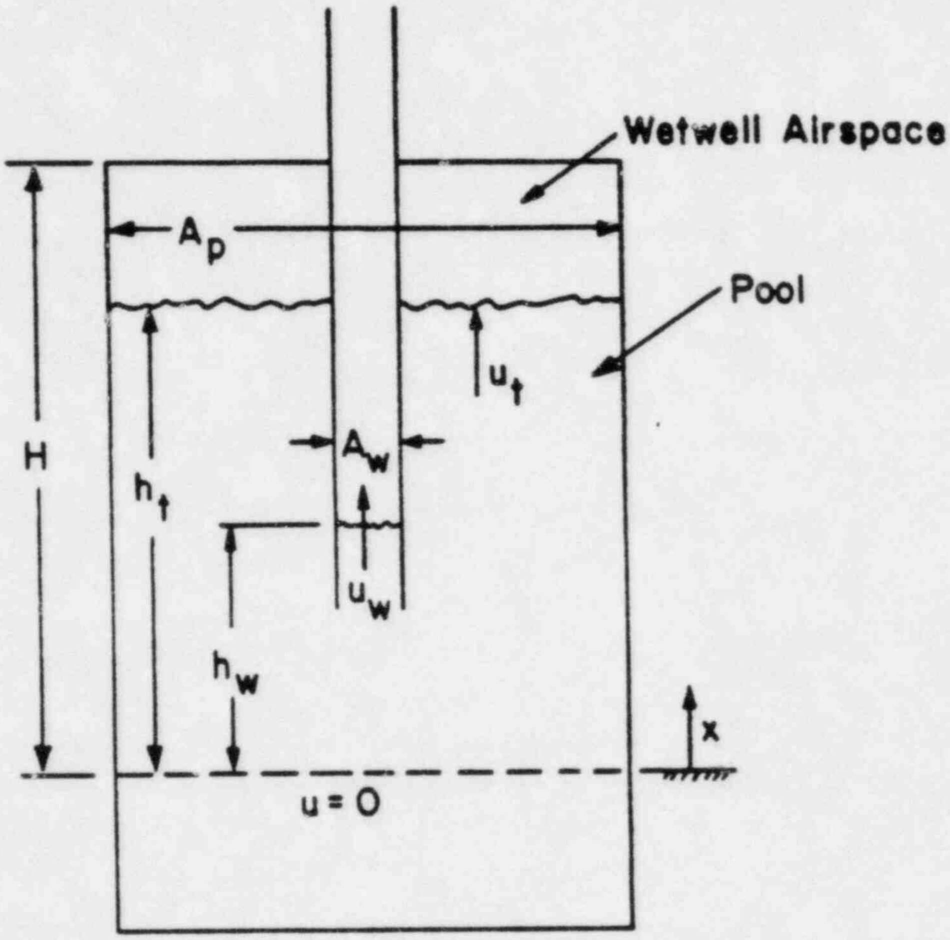

Figure 4. Details of the pool dynamic model around each downcomer.

with the lowering of the steam water interface in the downcomer. Assuming a unit condensation source in frequency space, a transfer function is then developed between the condensation source and the pressure in the drywell. Once this transfer function has been established, the condensation time history at the steam water interface can be extracted from a measured drywell pressure time history which is step 2 in Figure 1.

The model developed permits validation (step 3 in Figure 1) provided that an additional pressure time history, at another location in the suppression system, is available. With the condensation rate determined at the vent exit using a pressure time history from the drywell, the pressure history in the ring header was predicted and compared against measured data. The comparison was very favorable (Ref. 1).

In order to predict plant-unique vacuum breaker forcing functions, the key assumption is made that the condensation rate is a facility independent quantity. This assumption is supported by the observation that the condensation rate is fixed by local conditions at the vent exit; i.e., steam mass flow rate, noncondensibles and thermodynamic conditions, and that these local conditions vary slightly between plants. Using this condensation rate, the forcing function parameters given in Table 1 were used to compute expected and design loads across the Brunswick plant vacuum breakers (Ref. 1).

TABLE 1

Forcing Function Parameters for Brunswick

Parameter	Value Used In Computation*
Vent/pool area ratio	0.045
Drywell volume/main vent area ratio	532.87 ft**
Main vent area/downcomer area	0.99
Main vent length	37.32 ft
Header area/downcomer area	1.47
Header length	15.0 ft
Downcomer area	3.01 ft^2
Downcomer length	10.8 ft
Submergence head	3.0 ft wate

* The modeled plant is FSTF

** Group 2 value used even though Brunswick is 591.03 ft.

SUMMARY OF THE METHODOLOGY OF THE MARK I/MARK II VACUUM BREAKER VALVE MODEL (INCLUDING HYDRODYNAMIC EFFECTS)

During the Mark I shakedown tests, the vacuum breaker displacement time history was recorded. Use of a simple single-degree-of-freedom valve model resulted in large overly conservative predictions of the resulting valve dynamics. In an effort to reduce the conservatism in this test series, and additionally to relax the prediction of valve impact velocities in expected Mark II downcomer-mounted applications during chugging, a methodology was developed which uses the differential forcing function across the vacuum breaker (computed by the vent dynamic model) but includes the effect of torque alleviation as a consequence of valve flow (Ref. 2). With the valve in an open position, the pressure difference across the valve is not the pressure difference felt by the valve disc, because of flow effects across the open valve disc. This reduction in hydrodynamic torque is estimated by the following:

1. A linear analysis of the pressure field on either side of the closed valve permits the solution for pressure and velocity in the vicinity of the valve disc without flow.

2. The flow effect is modeled as a mathematical source/sink around the circumference of the open valve.

3. The local pressure and velocity fields permit evaluation of the strength of the flow source/sink.

4. The response of the valve to both flow and up and downstream pressure transients is computed as a superposition of these influences. In all cases flow tends to reduce the pressure load felt by the disc.

The 18" GPE valve characteristics for Brunswick are shown in Table 2.

TABLE 2

Vacuum Breaker Characteristics

for Brunswick

Vacuum breaker type	18" GPE Internal
System moment of inertia ($lb\text{-}in\text{-}s^2$)	24.0
System moment arm (in)	11.172
Disc moment arm (in)	11.47
System weight (lb)	49.8
Disc area (in^2)	375.85
System rest angle (rad)	0.0698
Seat angle (rad)	0.0698
Body angle (rad)	1.256
Seat coefficient restitution	0.6
Body coefficient restitution	0.6
Magnetic latch set pressure (psi)	0.25

RESULTS

The pressure time history shown in Figure 5 was used to drive a valve dynamic model with/without flow for the GPE valve with characteristics given in Table 2. The response of the valve for displacement and angular velocity are given in Figures 6 and 7. All results shown are for the expected pressure loading function with flow. Table 3 summarizes the valve impact data for both expected and design loading response.

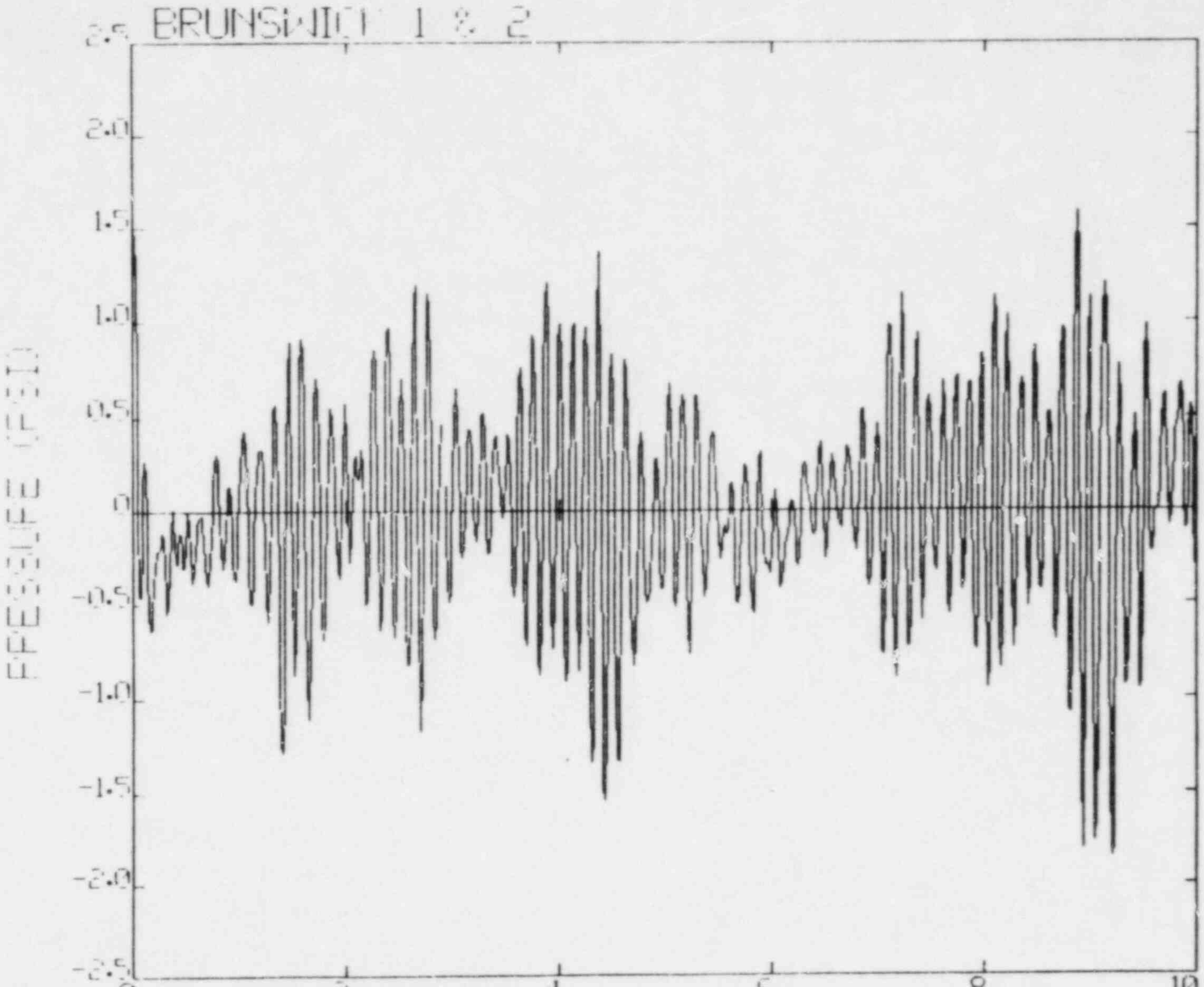

Figure 5a. Pressure time history predicted across a vacuum breaker located at the main vent-header junction in a Group 2, Mark I plant. Submergence has not been added. 0 - 10 seconds.

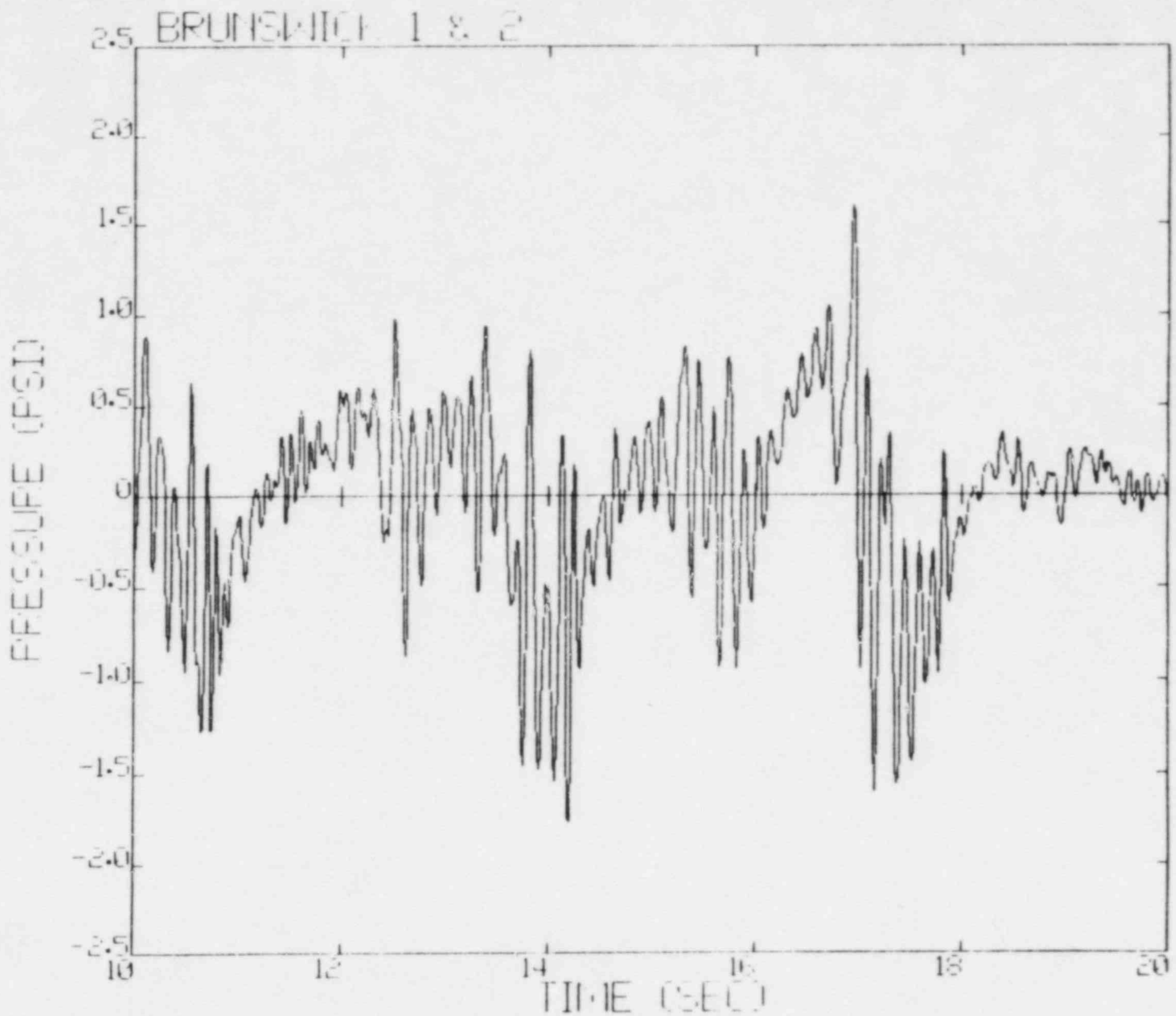

Figure 5b. 10 - 20 seconds.

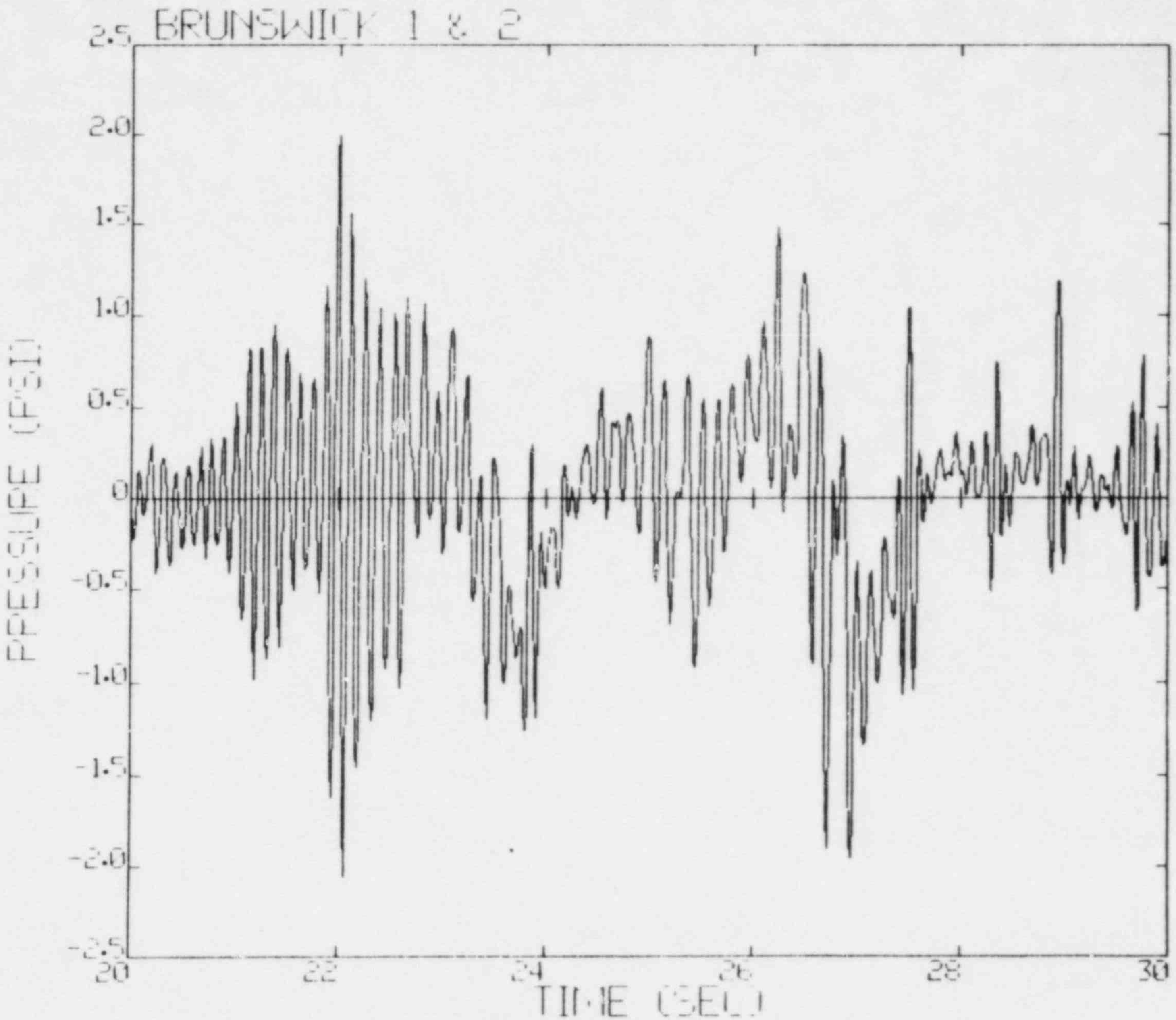

Figure 5c. 20 - 30 seconds.

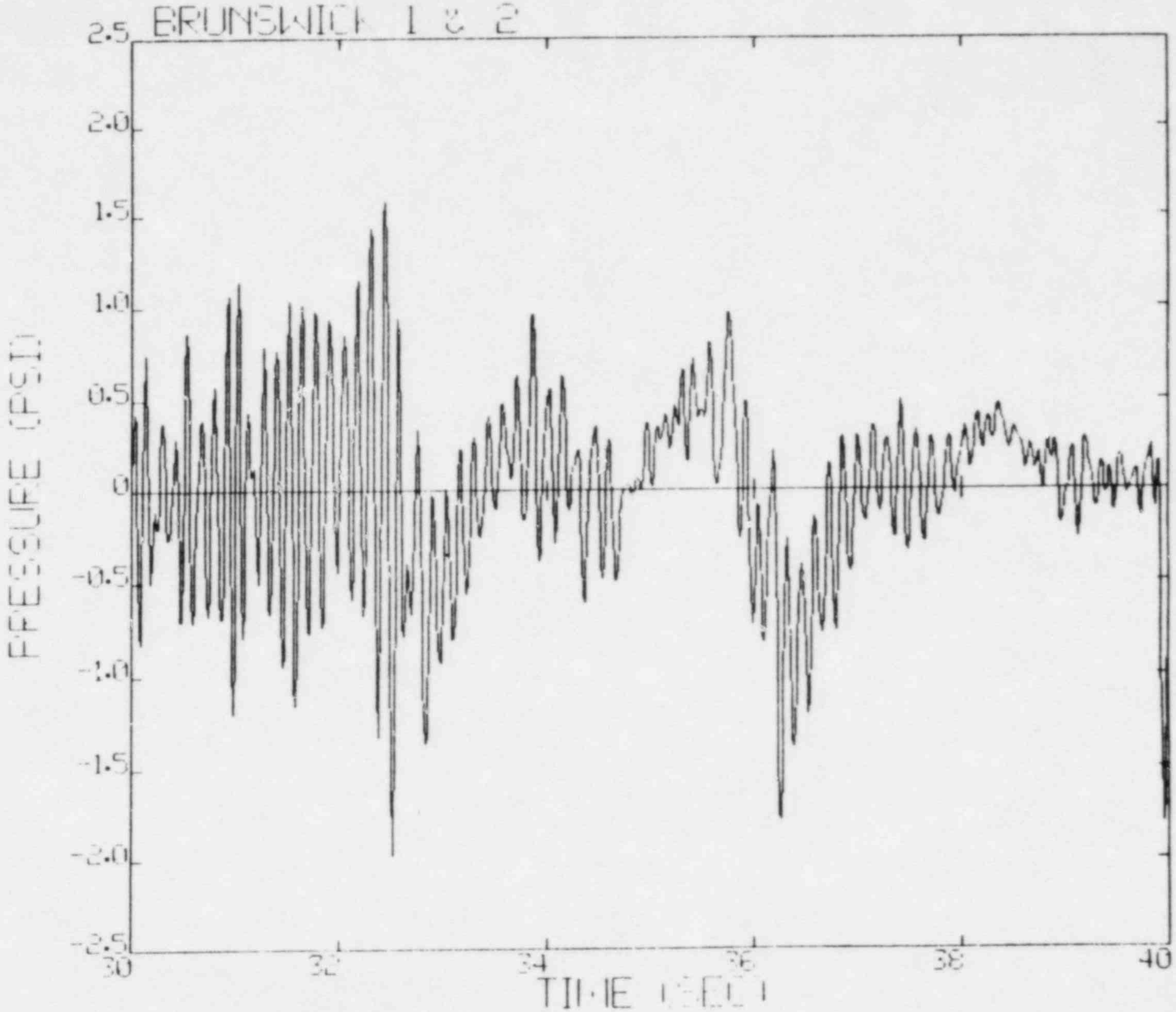

Figure 5d. 30 - 40 seconds.

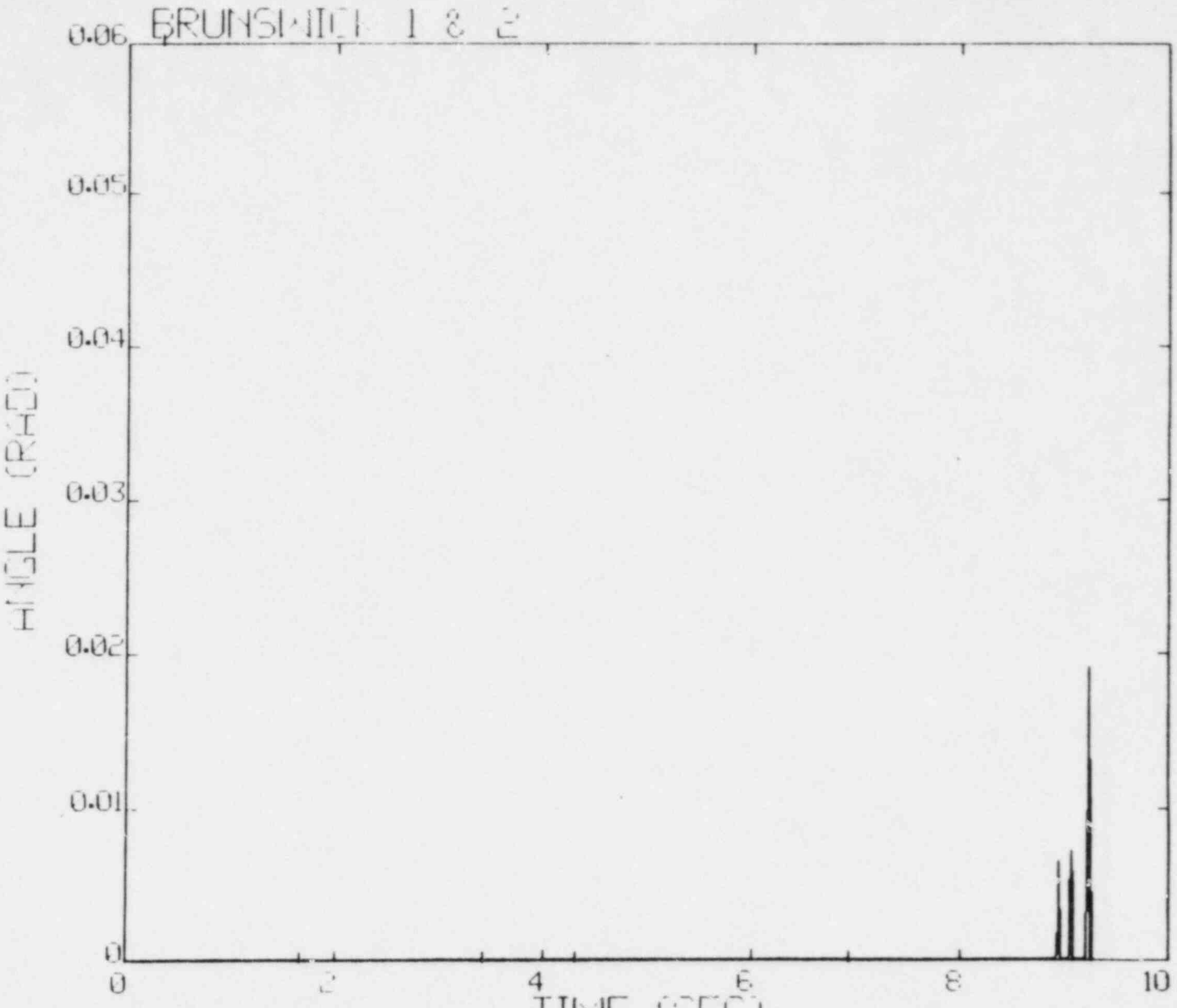

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Figure 6a. Displacement time history of the 18" GPE internal valve in Brunswick. 0 - 10 seconds.

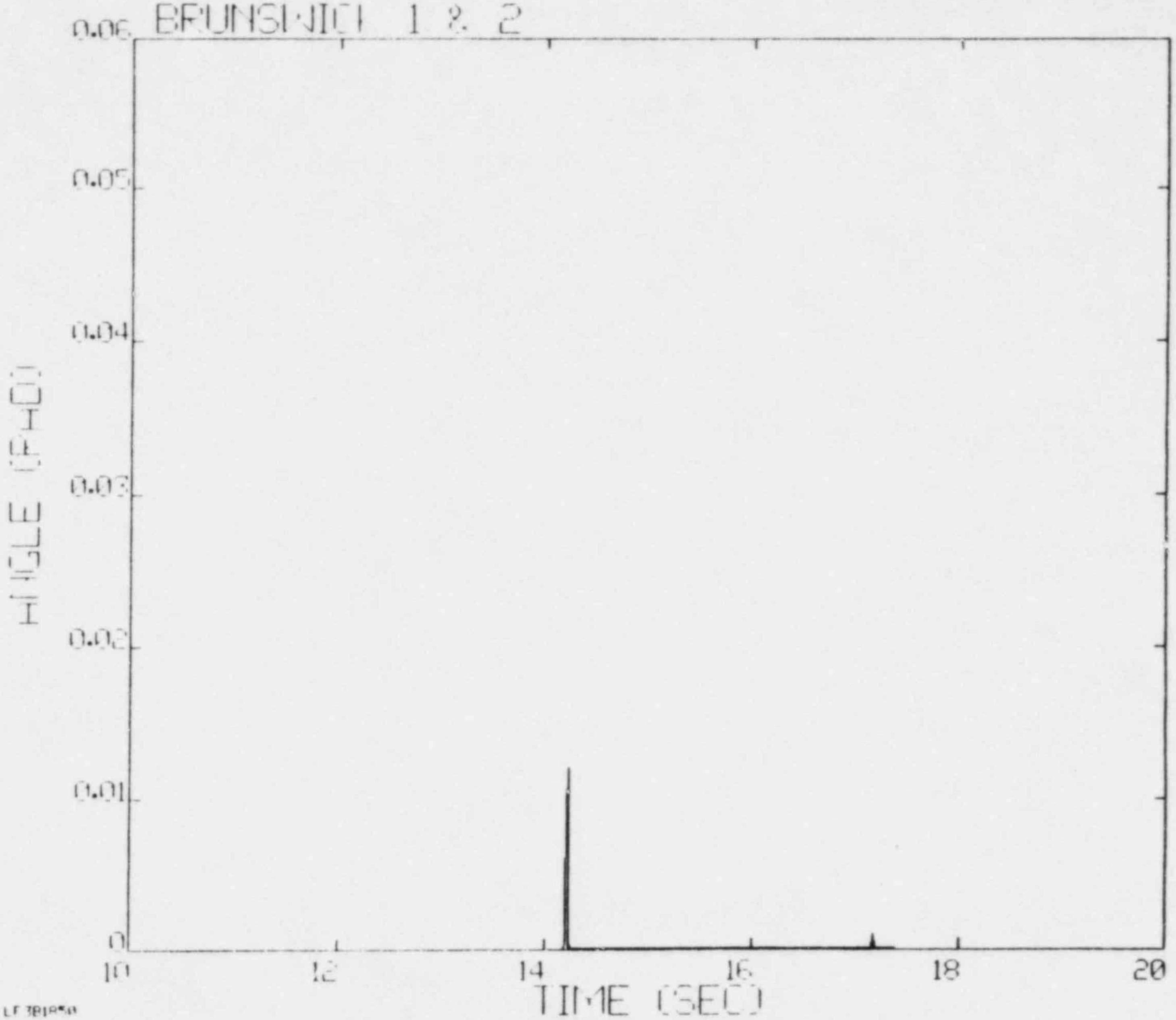

Figure 6b. 10 - 20 seconds.

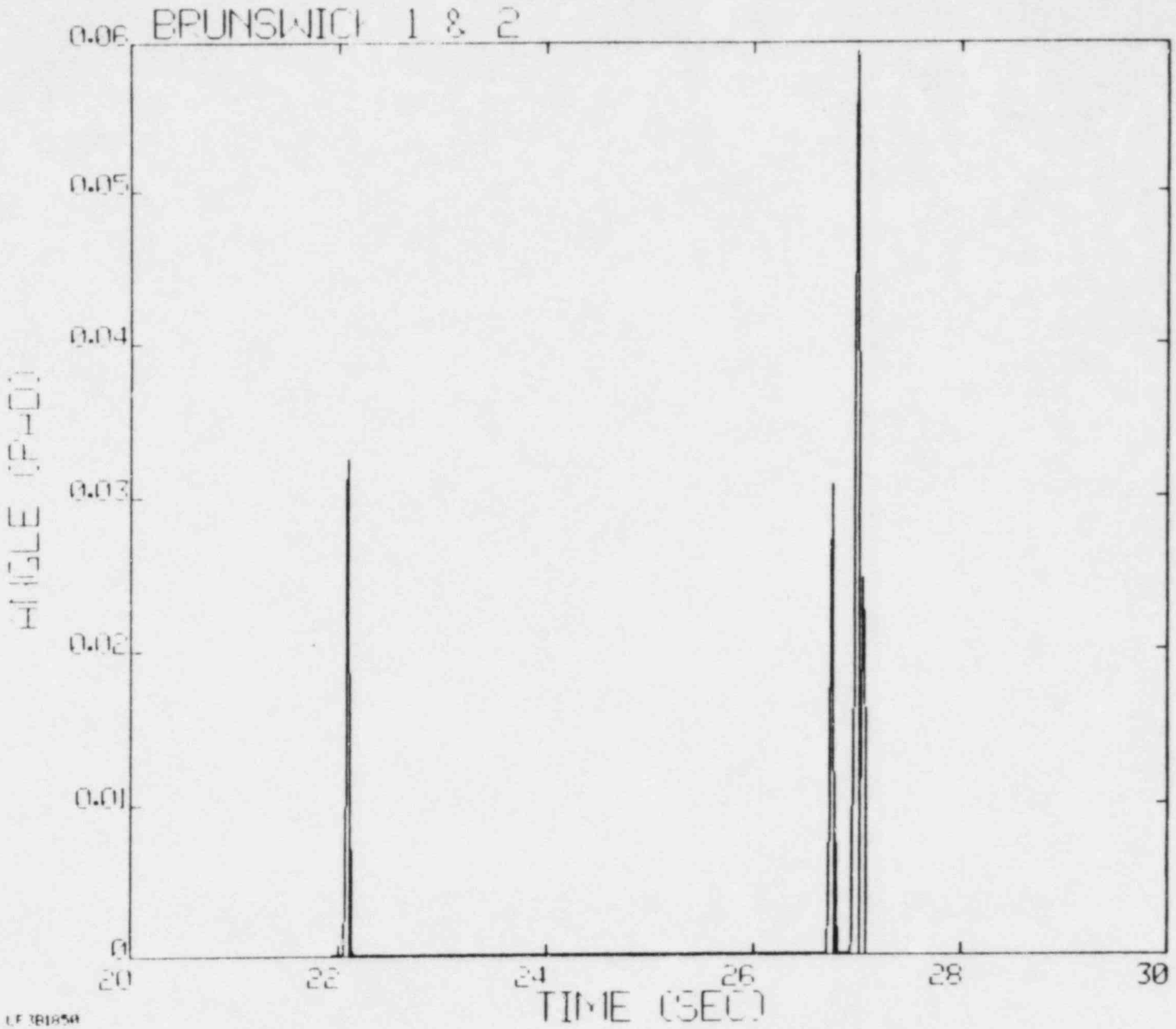

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Figure 6c. 20 - 30 seconds.

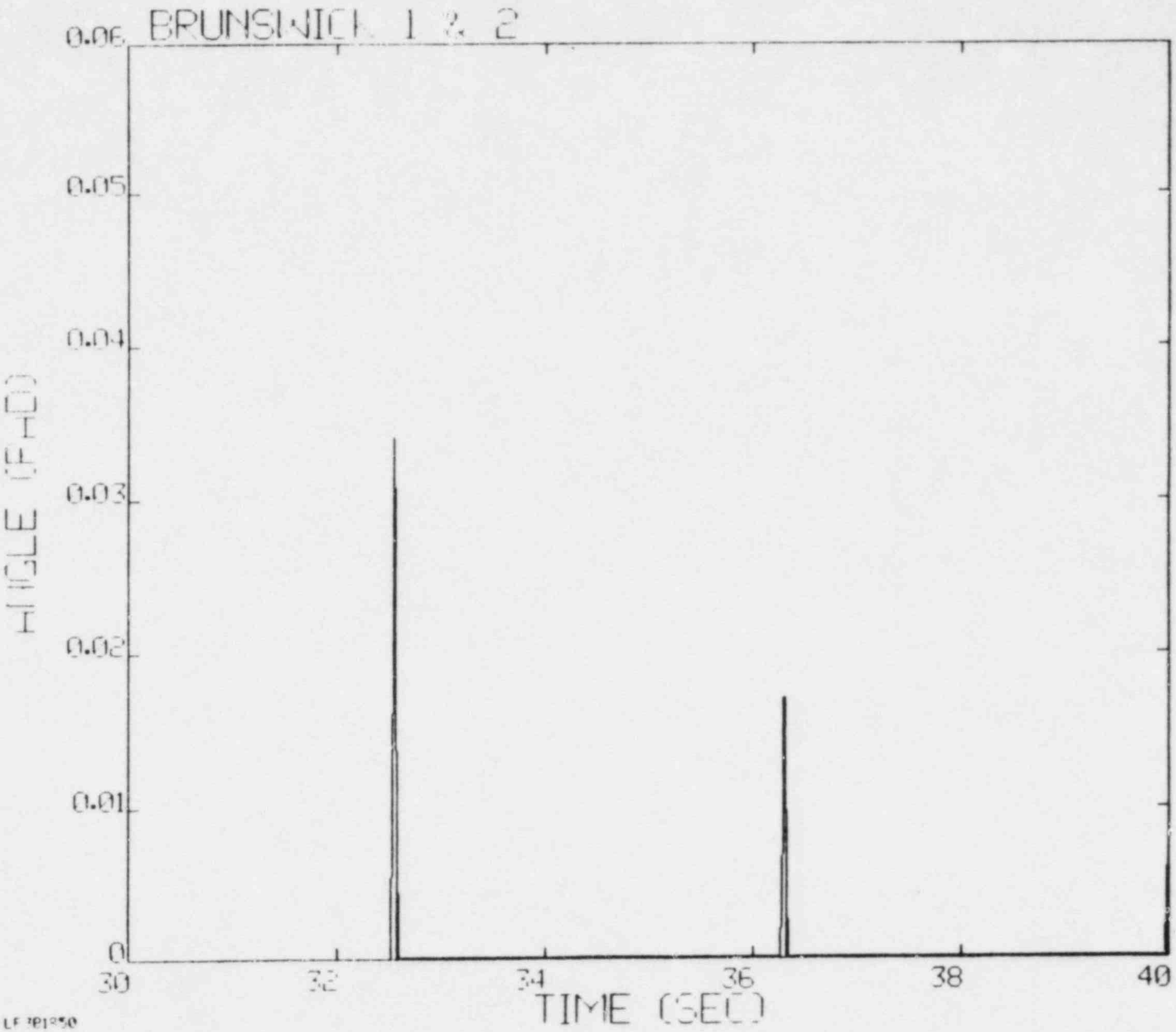

Figure 6d. 30 - 40 seconds.

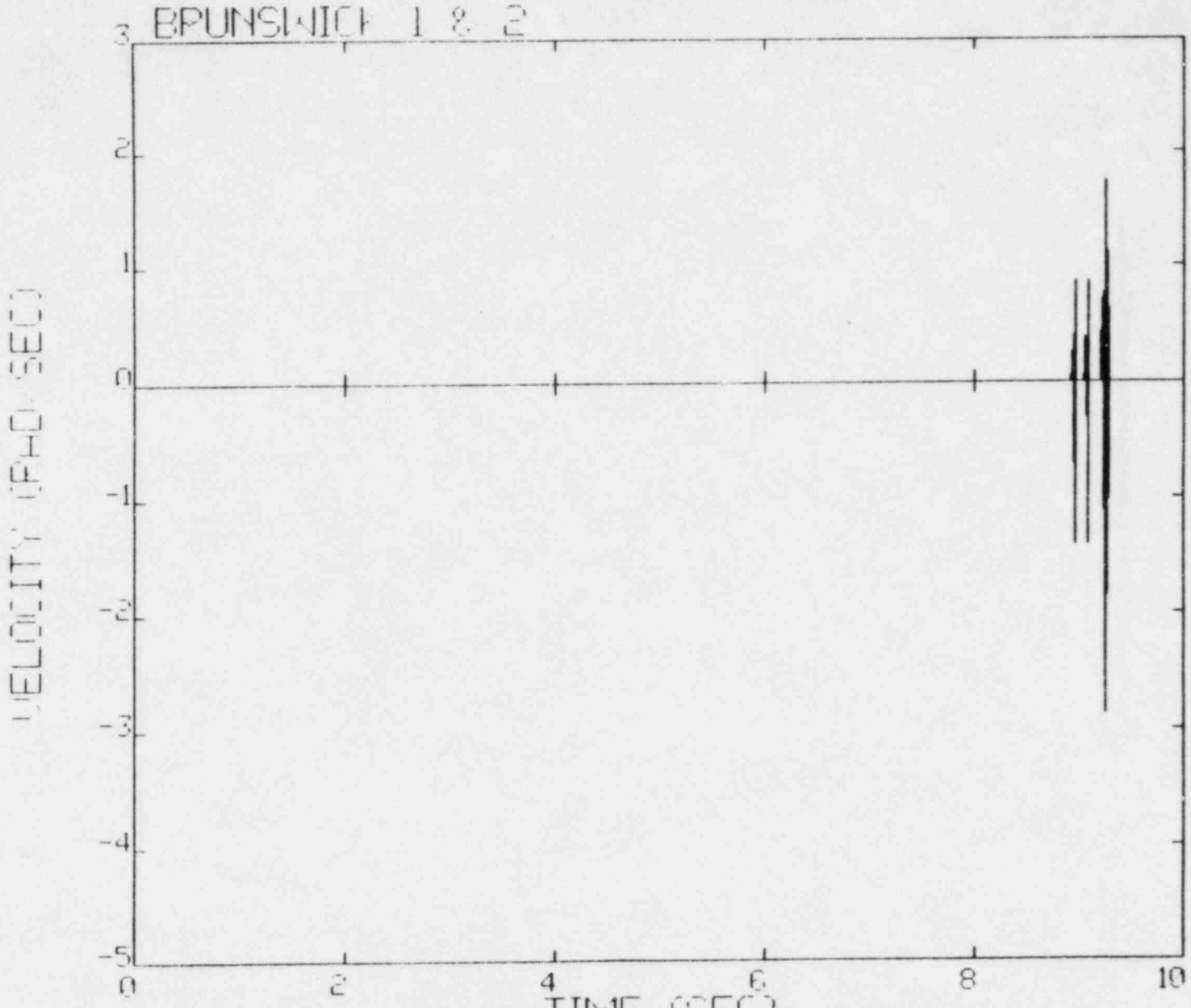

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Figure 7a. Angular velocity time history of the 18" GPE internal valve in Brunswick. 0 - 10 seconds.

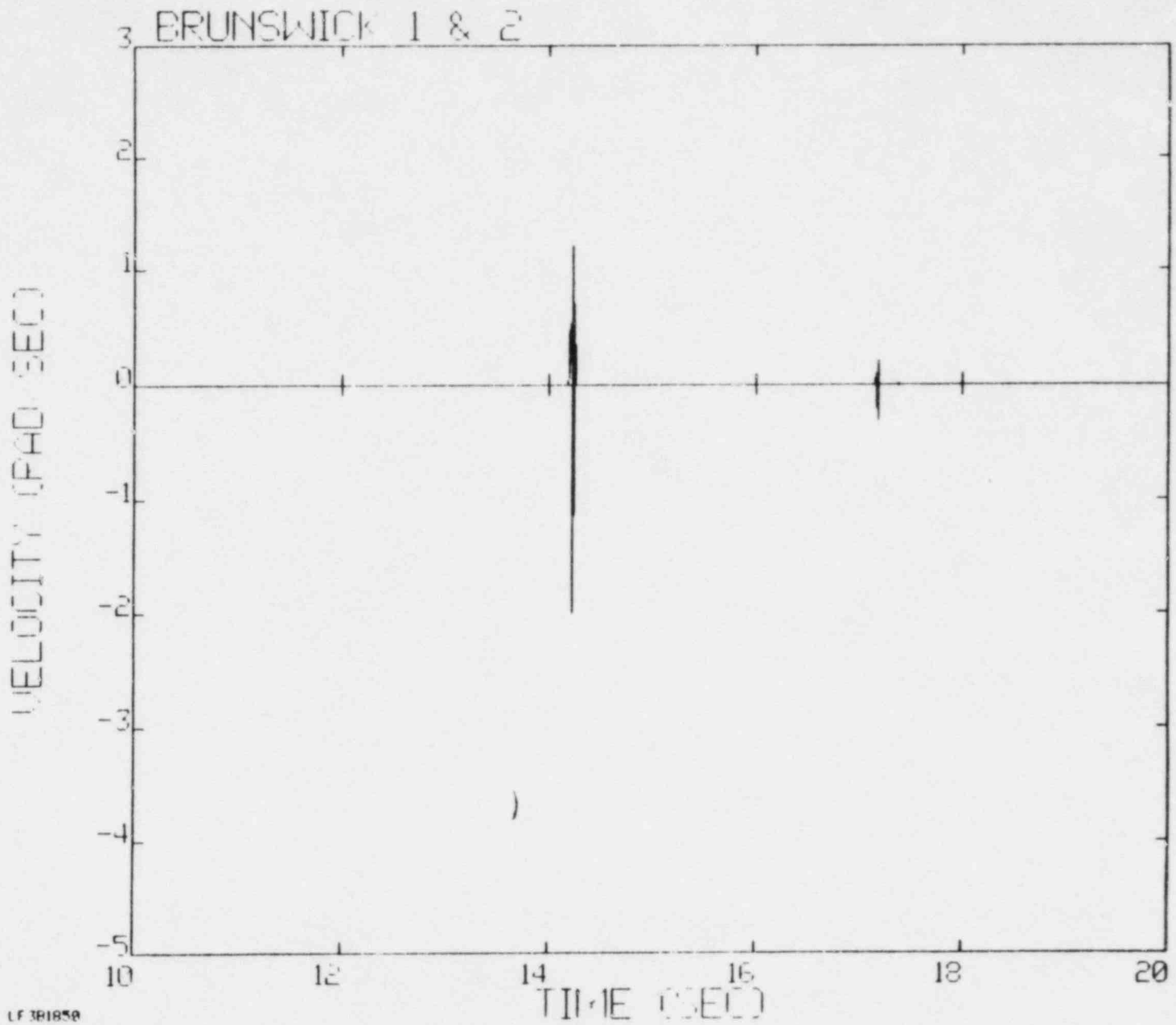

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Figure 7b. 10 - 20 seconds.

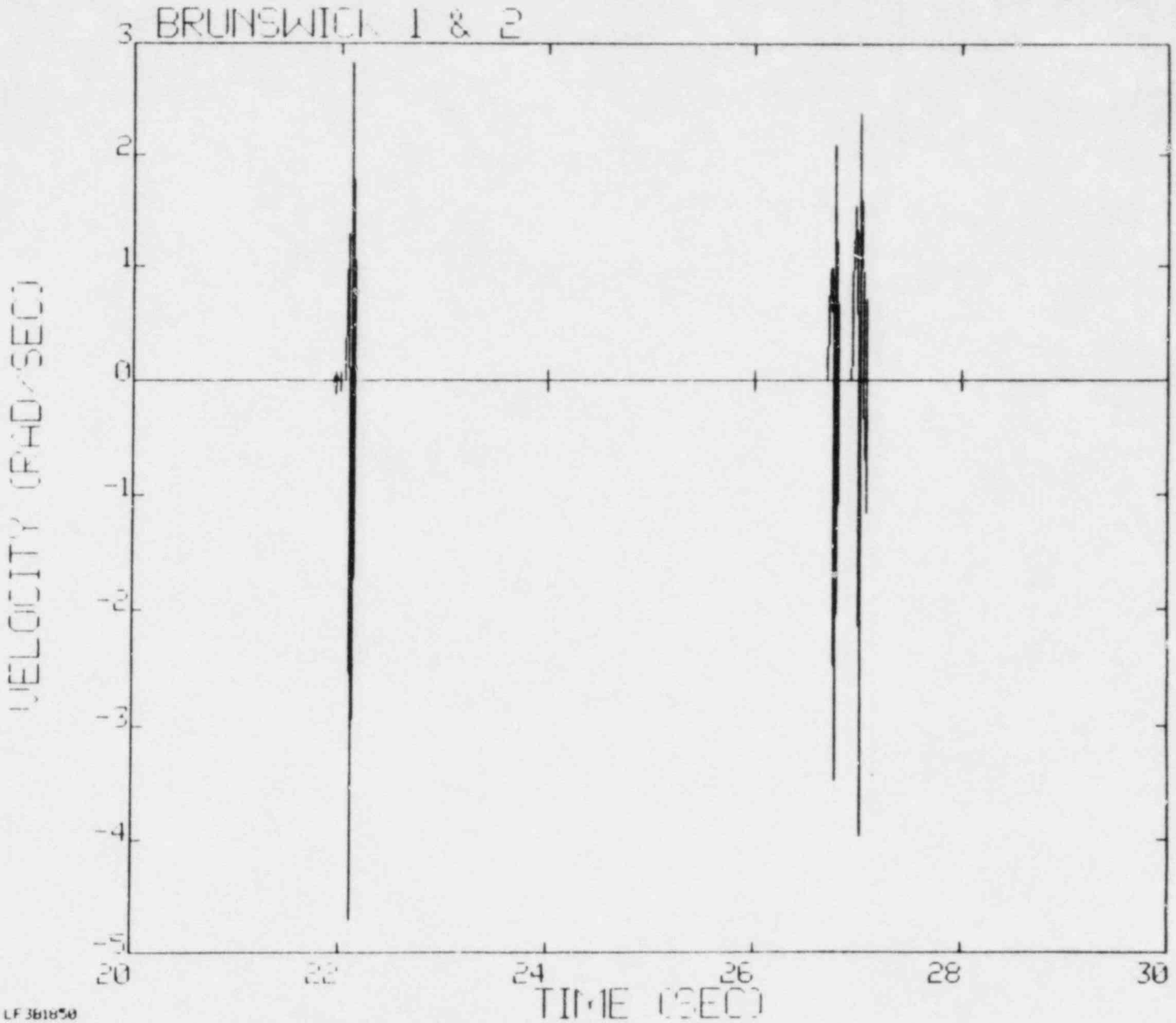

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Figure 7c. 20 - 30 seconds.

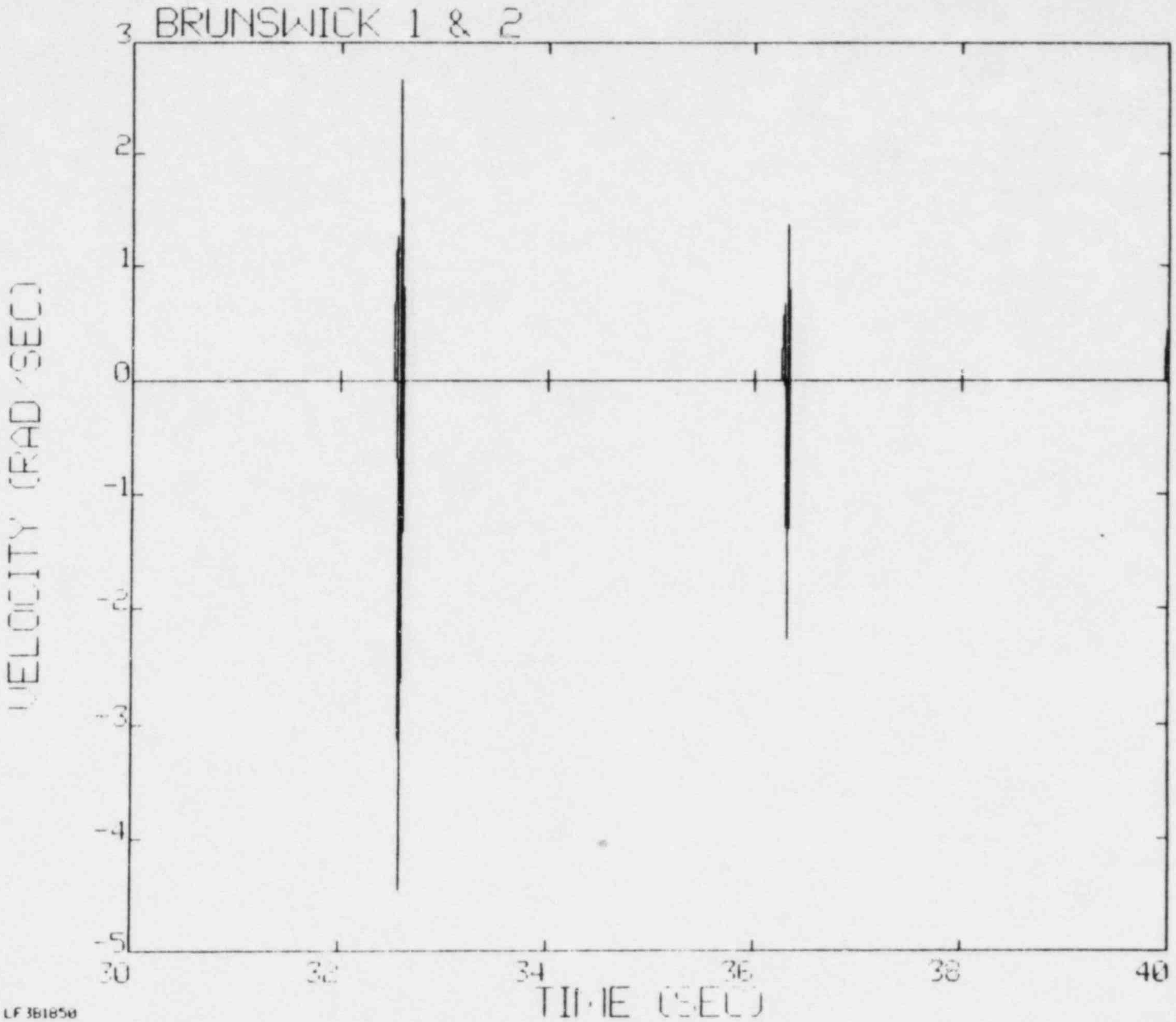

Figure 7d. 30 - 40 seconds.

REFERENCES

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

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

3. General Electric Company letter MI-G-43, July 9, 1982 Mark I Containment Program - Task 9.5.1, Architect Engineer Question Reply No. 315.