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Memorandum

Chief, Mechanical Branch

Denver, Colorado
August 13, 1974

Chief, Division of General Research HJC 10/9/74
Acting Chief, Division of Design JSB 10-10-74
ACTING
Chief, Hydraulics Branch

Oahe Flap Gate Model Study

Model studies were undertaken on a 1:12 scale model of a single bay and flap gate structure as discussed in a meeting with representatives of the Mechanical Branch on March 7, 1973. The study was to include primarily (1) visual observations of the gate at pump startup with both a full and empty canal downstream and (2) gate response to a pipeline rupture upstream of the flap gate which could result in damage to the pumping plant.

The model, Figure 1 attached, consisted of a head box with flow control gate and overflow section, two backflow gates in the side of the closed rectangular conduit section, the vertically mounted flap gate and head structure and an 18-inch-wide rectangular section of the downstream canal with a water level control gate on the downstream end. No trashracks were included in the model structure.

Instrumentation consisted of four pressure transducers placed as shown in Figure 2. A gate position indicator with a d.c. potentiometer and power supply was connected along with the transducers to an oscillograph with a common time base for measuring the transient flow conditions. Subsequently, a dye injection system was used with a motor-driven 35-mm camera capable of producing 2 to 4.5 frames per second, to investigate the virtual mass of water moving with the flap gate at the instant of impact with the seat.

Only one basic gate design was tested with two slight modifications to the gate arrangement. The gate was made of sheet metal and was pivoted on Teflon upper and lower bearings attached to a brass side shaft.

The first modification consisted of a solid wall extending downstream from the headwall and adjacent to the wide open gate. This was to act as a stop for the gate in the open position. The gate closure rate in the range of fully open to about 45 degrees open was slowed, but very little, if any reduction was noted in the slamming of the gate. As it would be desirable to speed up the closure rate when the gate is a considerable distance from the seat, and retard the rate when the gate nears the seat, the modification was eliminated.

The second modification consisted of tilting the gate slightly by moving the upper bearing mounting plate inward toward the centerline of the canal, and the lower bearing mounting plate slightly downstream from the headwall. This change makes the gate self-closing due to the gravitational weight component.

Very little background information was available on flap gate design. Use of circular, horizontally-mounted gates in several field installations has resulted in structural failures. A partial copy of a memorandum by John Parmakian, dated April 26, 1949, provided some information on closing times when pump shutoff occurs. Using the limits of parameters included in the memorandum, the time t_1 (seconds) measured from the instant of power failure until the flow is stopped at the discharge end of the conduit falls between 4.66 and 9.32 seconds. The time t_2 required to reach maximum backflow (from the instant of power failure) occurs between 9.3 and 18.6 seconds. The closing time in seconds based on a uniform angular acceleration of the gate and an estimated maximum safe slam velocity of 3 feet per second, would be about 10.8 seconds. From the model data, closure times appeared to be somewhat faster depending on the size of backflow gate opening (used to simulate a rupture in the pipeline).

A curve was developed, Figure 3, from the model, of backflow area (simulated conduit rupture area) versus flap gate closing time. With an instantaneous total rupture, the shortest closure time was approximately 7 seconds (2 seconds model). The curve for the self-closing gate deviated from the initial vertically-mounted gate for small rupture areas only. Figure 4 contains photos of the closing gate immediately before impact (A) and at impact (B). The latter photo represented a total instantaneous upstream conduit rupture (approximately 7 second closure prototype). The initial photo represented approximately a 12 second closure. Figure 5 is an oscillograph record of the dynamic response of gate closure.

Tests were made to determine if overtopping of the head structure would occur if the flap gate were closed, the canal water surface at elevation 1716.5, and a 300 cfs filling rate from a single centrifugal pump were applied to the upstream side of the gate. Figure 2 shows the transient response of the system, and Figure 6A shows the actual model photograph. As seen in the photo, no overtopping occurs as only a slight differential was required to open the gate. Figure 6B is a photo of the same upstream filling rate with an empty canal.

An attempt was made to determine the volume of water that should be considered as moving with the gate in order to determine the loading at impact. The procedure consisted of simultaneous closure of the head gate with opening of the backflow gate, along with injecting dye as backflow began. A series of colored photos was taken as the gate began to move and continued until after closure was complete. From the photos, it was possible to determine a point in the dye stream where no further upstream movement occurred at the time of impact. The dye was injected from a six-point manifold arranged across the canal section at four different depths. A series of photos was taken for each depth. A grid painted on the canal section invert helped determine dye movement. The canal volume was integrated throughout the width at the points determined as above for all depths and a volume value arrived at.

Figure 7 consists of a series of lines plotted for slamming velocities based on an average for the last 20 degrees of travel and considering the virtual mass of water obtained from the dye injection tests. These curves indicate the necessity for retarding the impact by some means of hydraulic or mechanical damping, to prevent structural damage.

One additional item of consideration is the necessity of preventing ice formation which could eliminate free gate travel during winter months.

R. L. KING

Attachments

Copy to: ~~1~~330 (2)
220
(with attachments to each)

Note: This memo was in final preparation when Tom Isbester began a long period of absence because of illness. We apologize for the delay.

KING

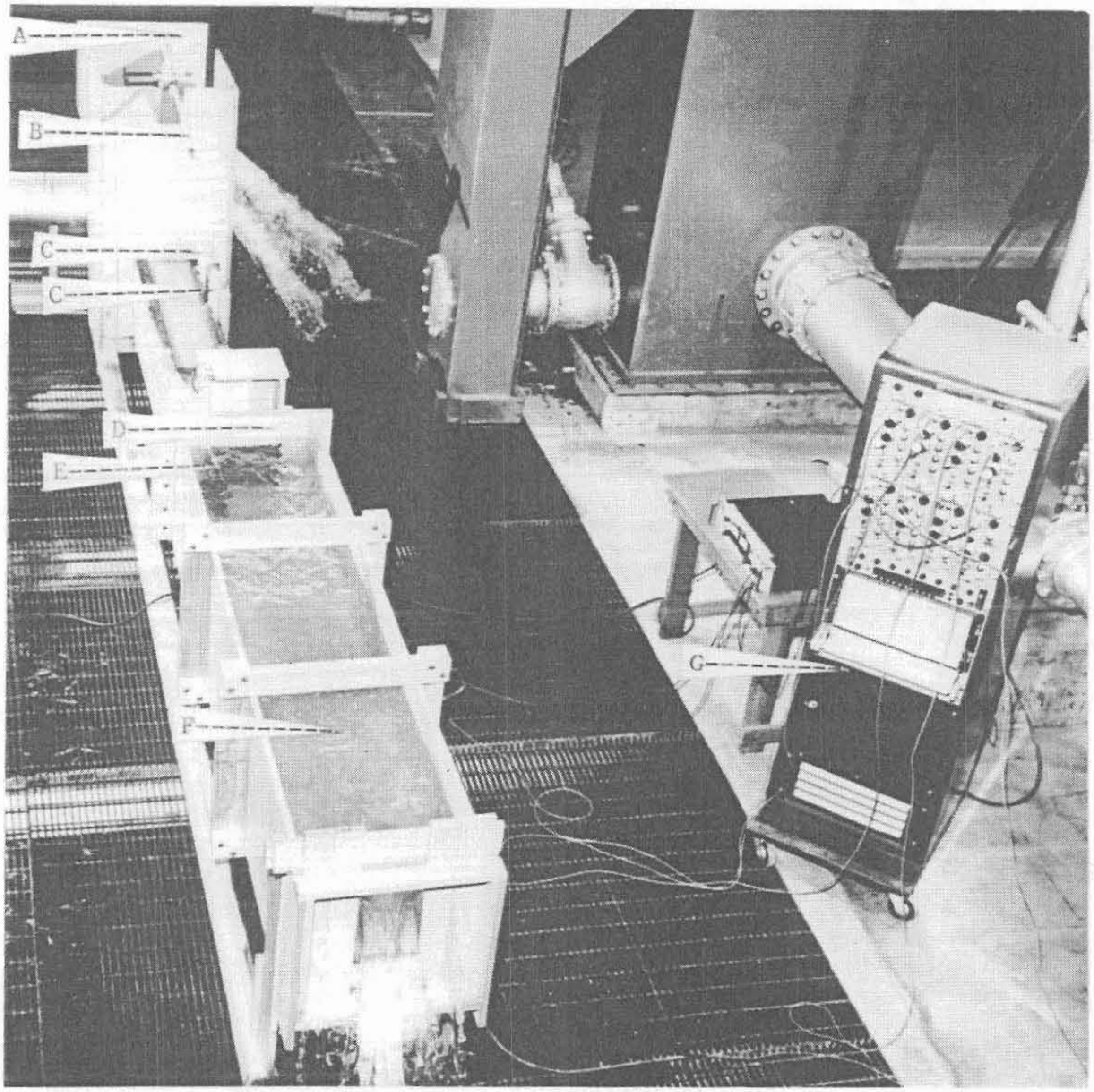
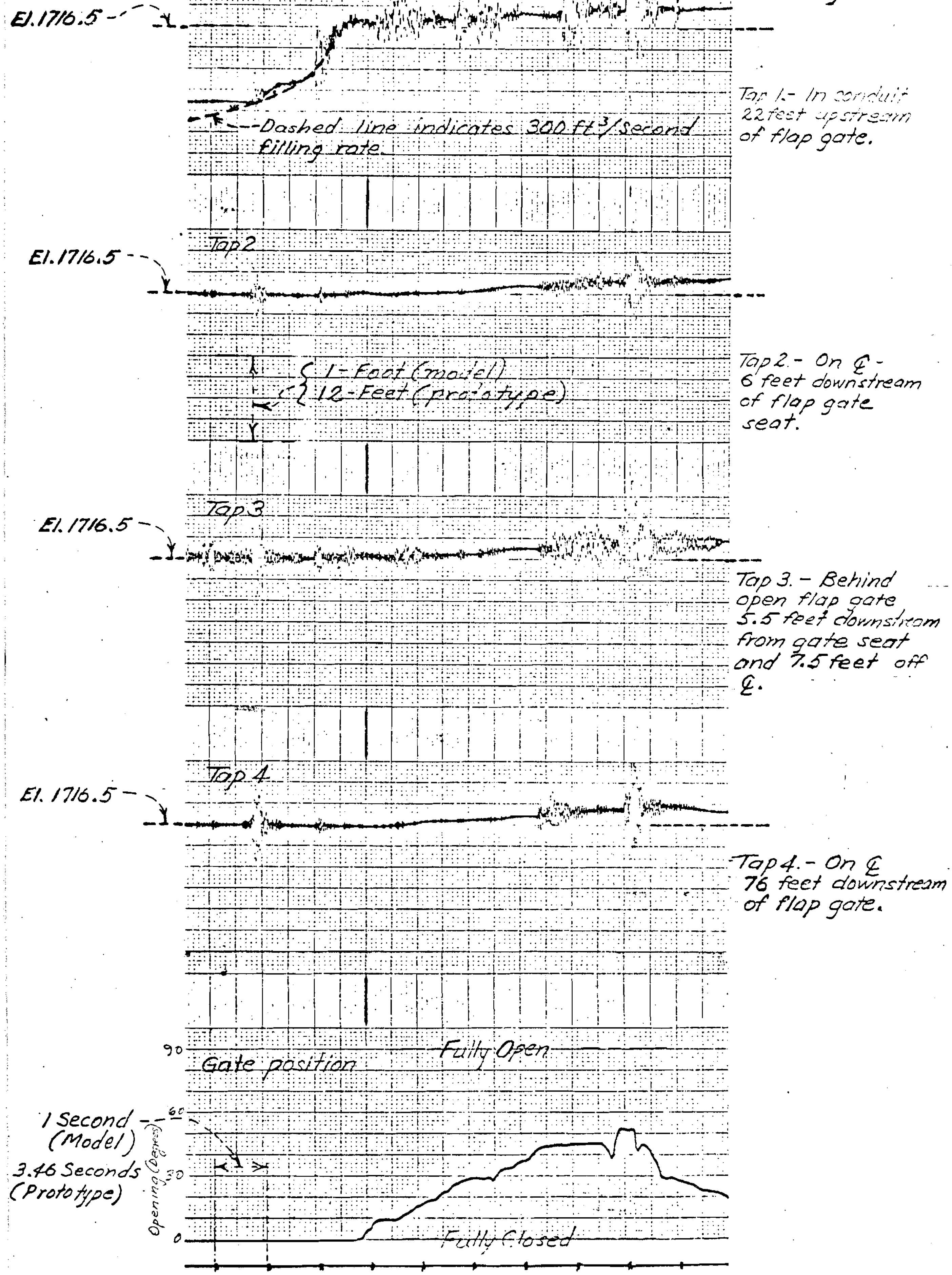


Figure 1. 1:12 Scale model of the Oahe flap gate showing the following:

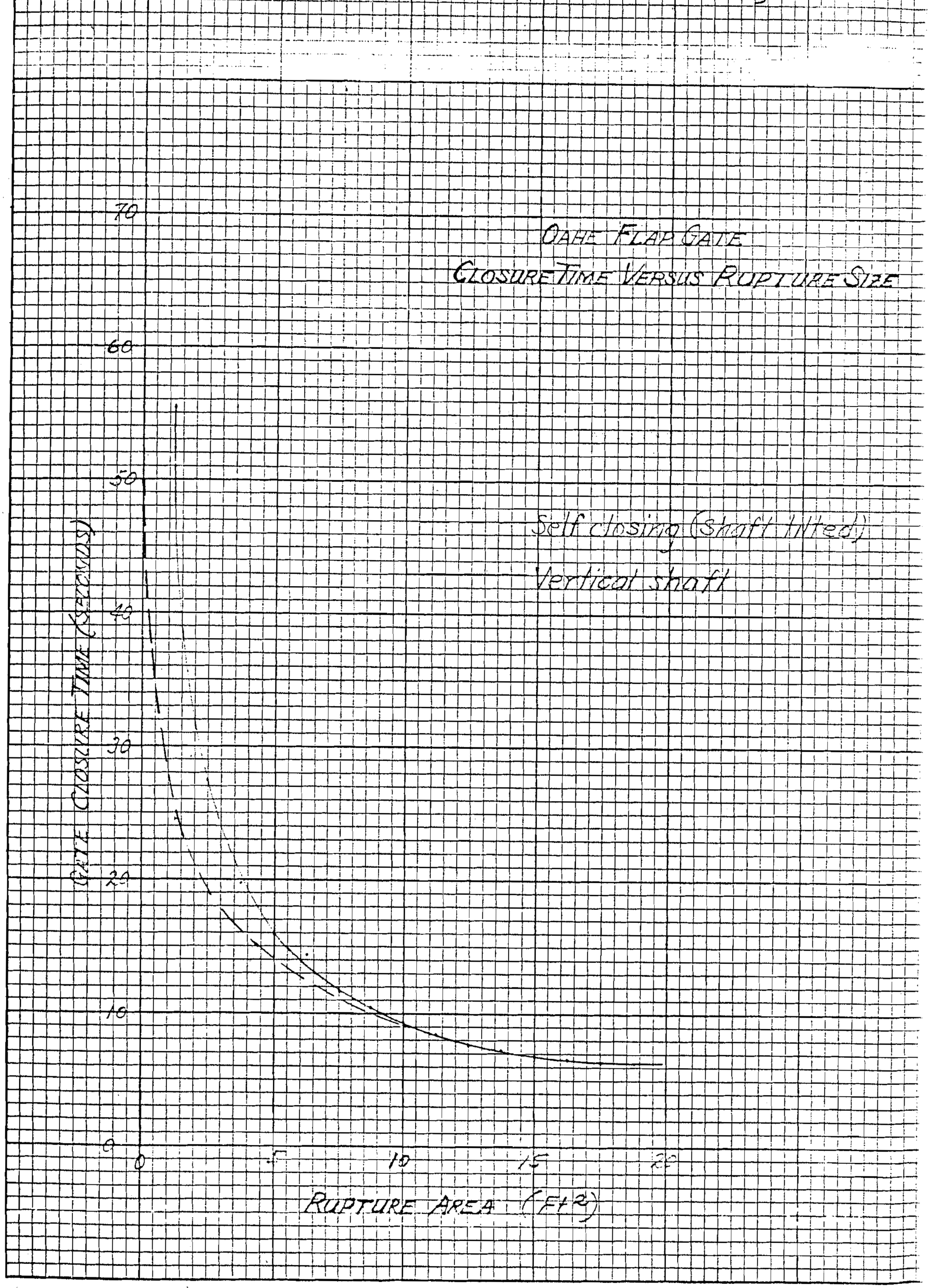
A - Head box with waste chute.
B - Control gate lever.
C - Back flow gates-2 ea.
D - Head wall.
E - Flap gate.
F - Canal section with tail gate.
G - Recording system.

Figure 2



GATE RESPONSE WHEN FILLING CONDUIT WITH 300 FT³/SEC., FULL DOWNSTREAM CANAL

Figure 3


OAHE FLAP GATE
CLOSURE TIME VERSUS RUPTURE SIZE
Self closing (Shaft filled)
Vertical shaft
GATE CLOSURE TIME (SECONDS)
RUPTURE AREA (Ft²)
70
60
50
40
30
20
10
0
0
5
10
15
20

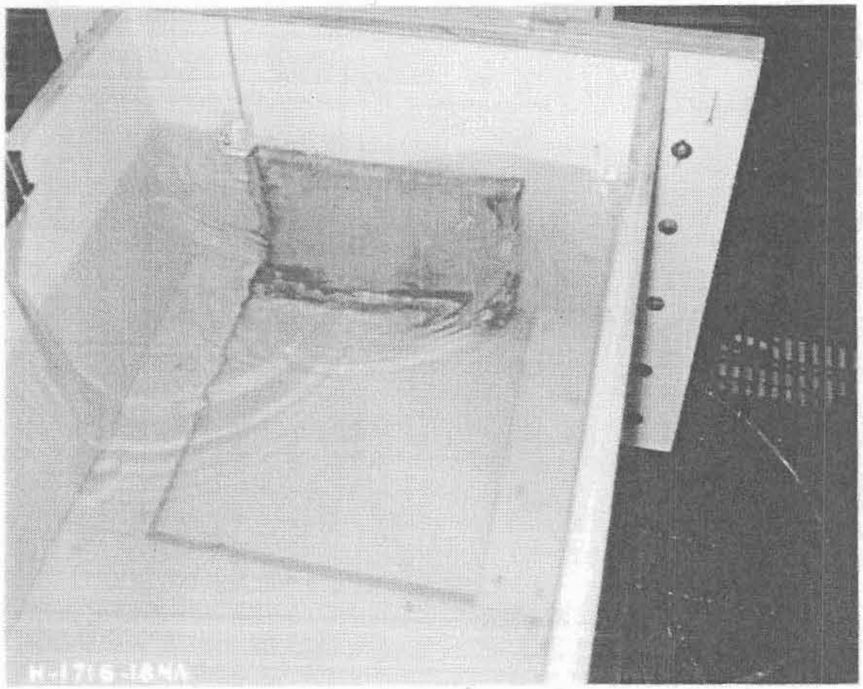


Figure 4A. Gate in a closing sequence prior to impact with wall. Photo represents about a 12-second closure.

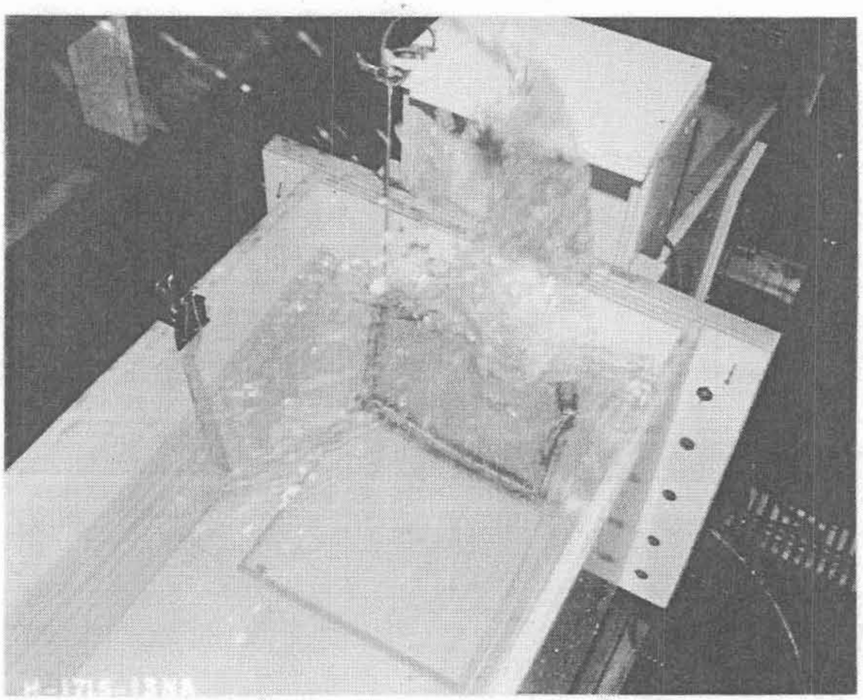
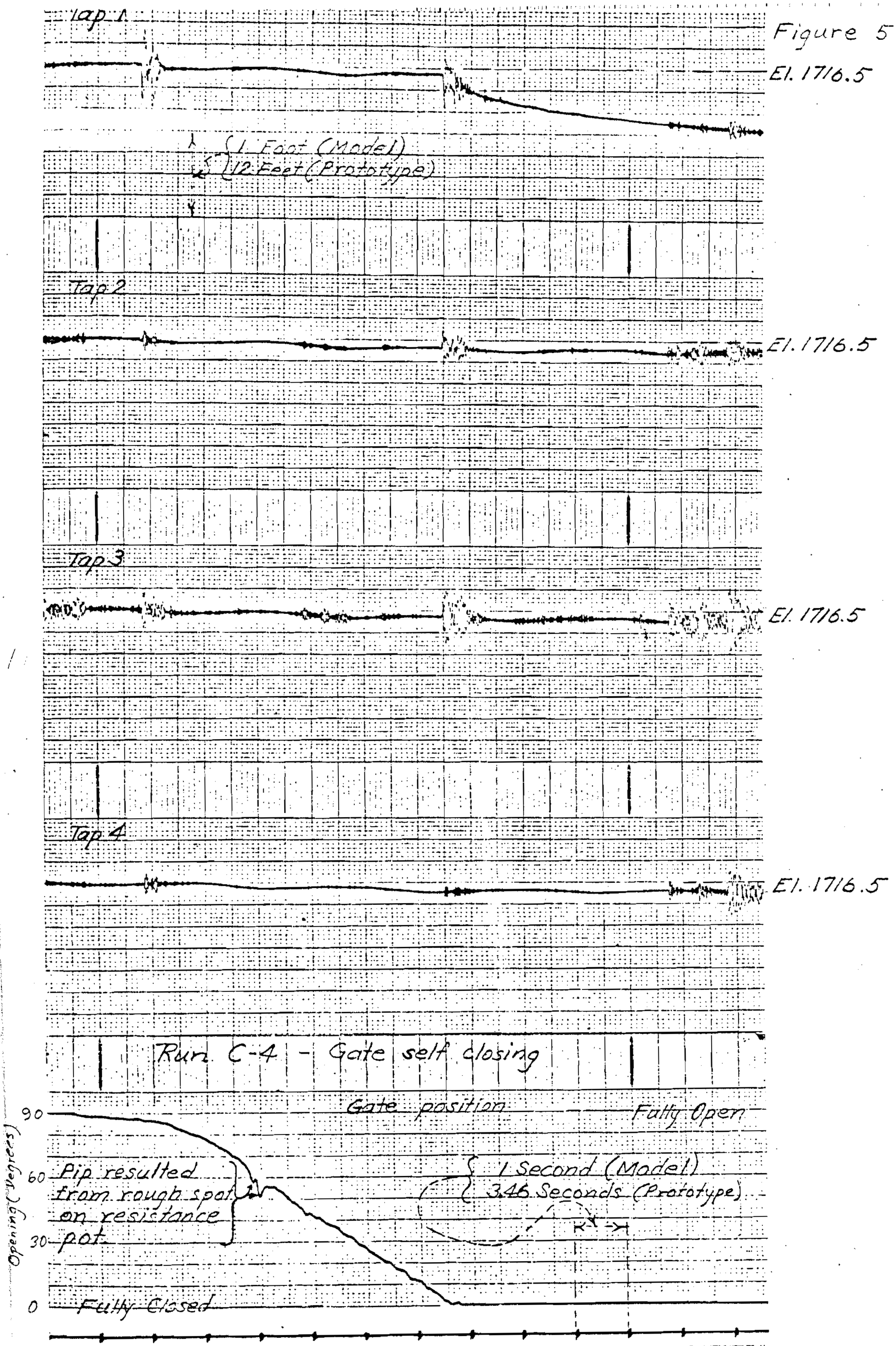


Figure 4B. Gate in a closing sequence at time of impact with wall. Photo represents about a 7-second closure (instantaneous complete rupture).



TYPICAL FLAP GATE CLOSURE RECORD

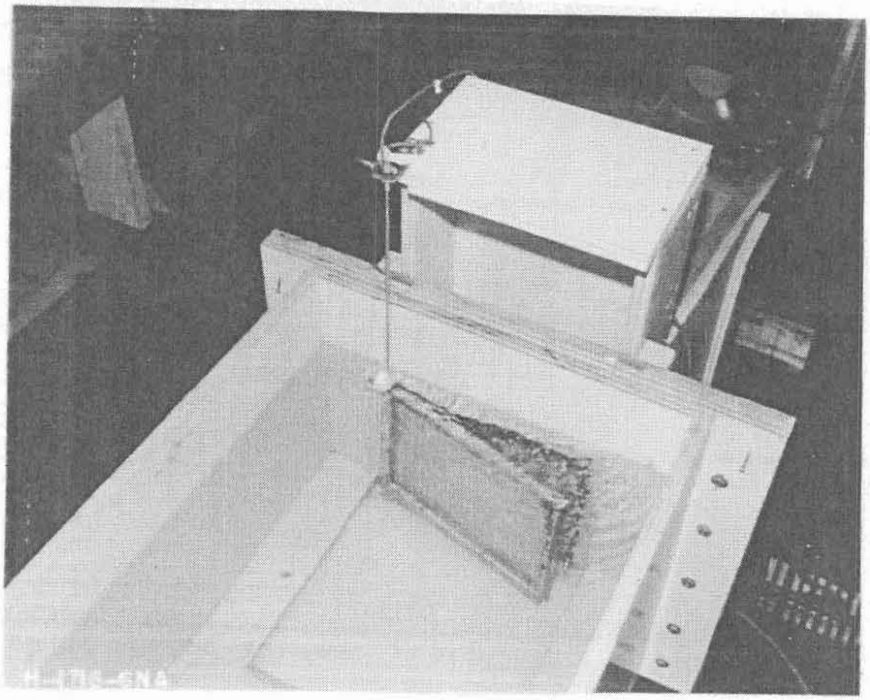


Figure 6A. Gate response while filling the upstream conduit at 300 ft.^{3}/sec with a full canal and initially closed flap gate.

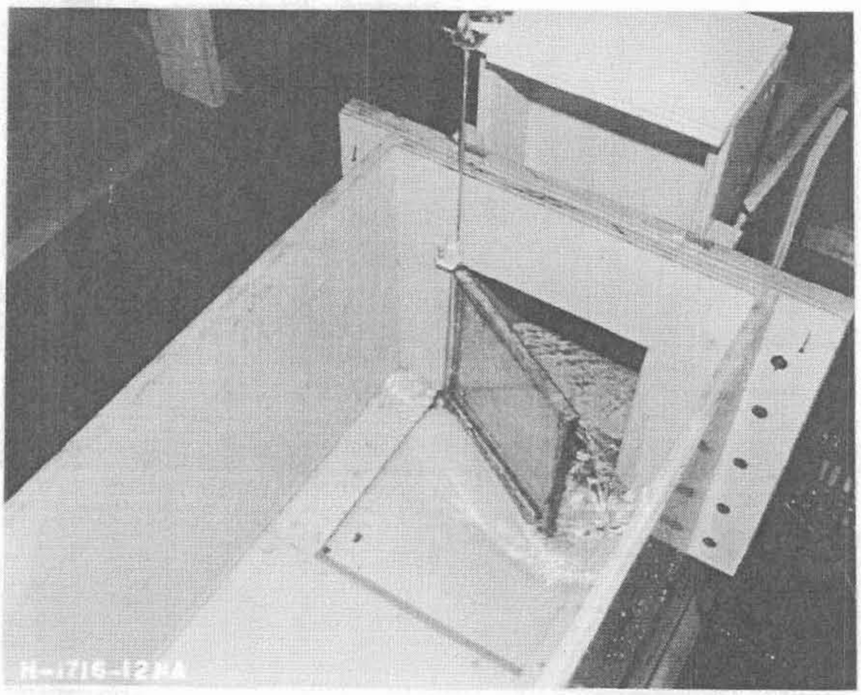


Figure 6B. Gate response while filling the upstream conduit at 300 ft.^{3}/sec with an empty canal and initially closed flap gate.

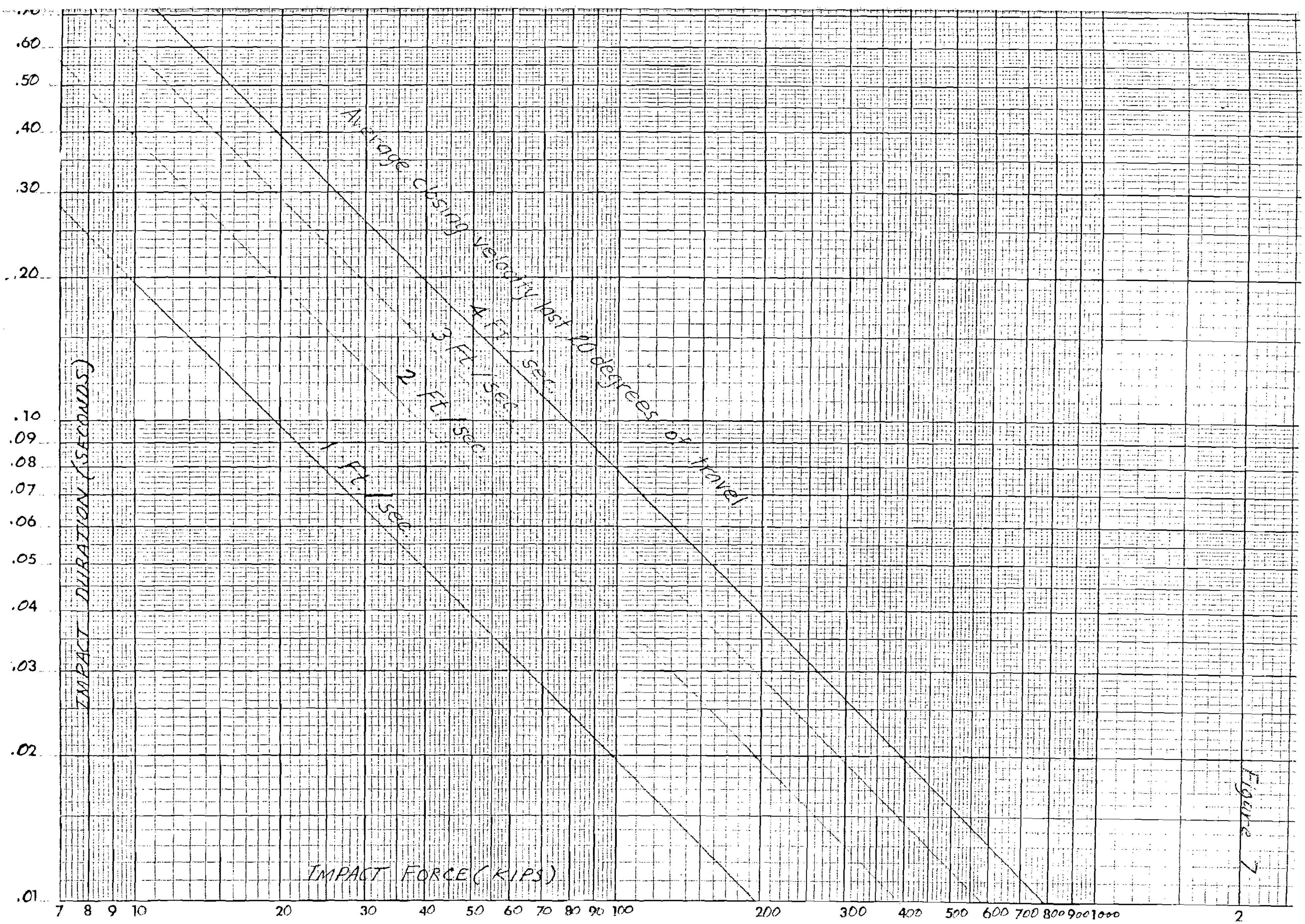


Figure 7
Average closing velocity last 10 degrees of travel
4 Ft./sec.
3 Ft./sec.
2 Ft./sec.
1 Ft./sec.
IMPACT DURATION (SECONDS)
IMPACT FORCE (KIPS)
.60
.50
.40
.30
.20
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
7 8 9 10 20 30 40 50 60 70 80 90 100 200 300 400 500 600 700 800 900 1000 2