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Bureau of Reclamation

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HYDRAULICS BRANCH
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PAP 337

254

511.

MAR 4 1976

Memorandum

To: Regional Director, Salt Lake City, Utah
Regional Director, Sacramento, California

From: Chief, Division of Design

Subject: Transmittal of Report "Relief Panel Requirements to Reduce Waterhammer Pressures in the Proposed Retrofitted Selective Withdrawal System at Flaming Gorge Dam"

Enclosed for your use is a report titled "Relief Panel Requirements to Reduce Waterhammer Pressures in the Proposed Retrofitted Selective Withdrawal System at Flaming Gorge Dam."

The report deals specifically with the design proposed at Flaming Gorge Dam and presents a good general engineering analysis of the hydraulic transient problem. The waterhammer pressures generated are computed and methods of alleviating the pressure rises are described in the report.

R S Salisman

PAP 337

Enclosure

Blind to: 220 (2)
250 (2)
700 (2)
1300 (2)
✓1500 (2) - sent 1530 a copy

ALewey:bjc 2/27/76

RELIEF PANEL REQUIREMENTS TO REDUCE WATER-HAMMER PRESSURES IN THE PROPOSED RETROFITTED SELECTIVE WITHDRAWAL SYSTEM FLAMING GORGE DAM

by

Allen B. Lewey

Special Studies and Testing Section
Mechanical Branch
Division of Design

February 9, 1976

I. Introduction

Water withdrawal from a reservoir for power generation is normally taken from a depth considerably below that of the water surface. Withdrawal from such a depth produces low temperature waters downstream from the generating site. Because of the environmental stress that the low temperature waters produce, it is desirable to withdraw water from the reservoir at an elevation that will provide suitable downstream water temperatures.

Existing trashrack intake structures such as the Flaming Gorge (figure 1) can be retrofitted with a selective withdrawal system. It is noted that even though a retrofit is found desirable, considerable installation difficulties will be encountered of which a few are:

A. Divers must ordinarily be used to install the structure. The elapsed time per dive and the total allowable underwater time per day is limited. Visibility is limited at the working depths.

B. The structure itself will be heavy, bulky, and awkward to maneuver.

C. Existing structural components, such as trashracks, must be removed, modified, and/or designed around.

Along with the difficulties of constructing the selective withdrawal system, a major concern is the additional water-hammer pressures generated due to installation of the selective withdrawal system. A water-hammer computational study has been performed on the proposed selective withdrawal system at Flaming Gorge Dam. This report contains a description and results of that study. All information, unless otherwise stated, pertains to the selective withdrawal system itself. Times given with reference to water-hammer pressures are in seconds after the initiation of wicket gate closure.

Conclusions

The study has shown that the water-hammer pressures generated in selective withdrawal systems are dependent upon the relief panel area provided, the length of time to initiate opening (delay time), and the opening time (response time). The dependency of the head rises generated, on these quantities, in the proposed retrofitted Flaming Gorge selective withdrawal system is shown in figure 2. A parametric study was performed using these quantities since panels for the Flaming Gorge System have not been developed. Curve 3 of figure 2 is

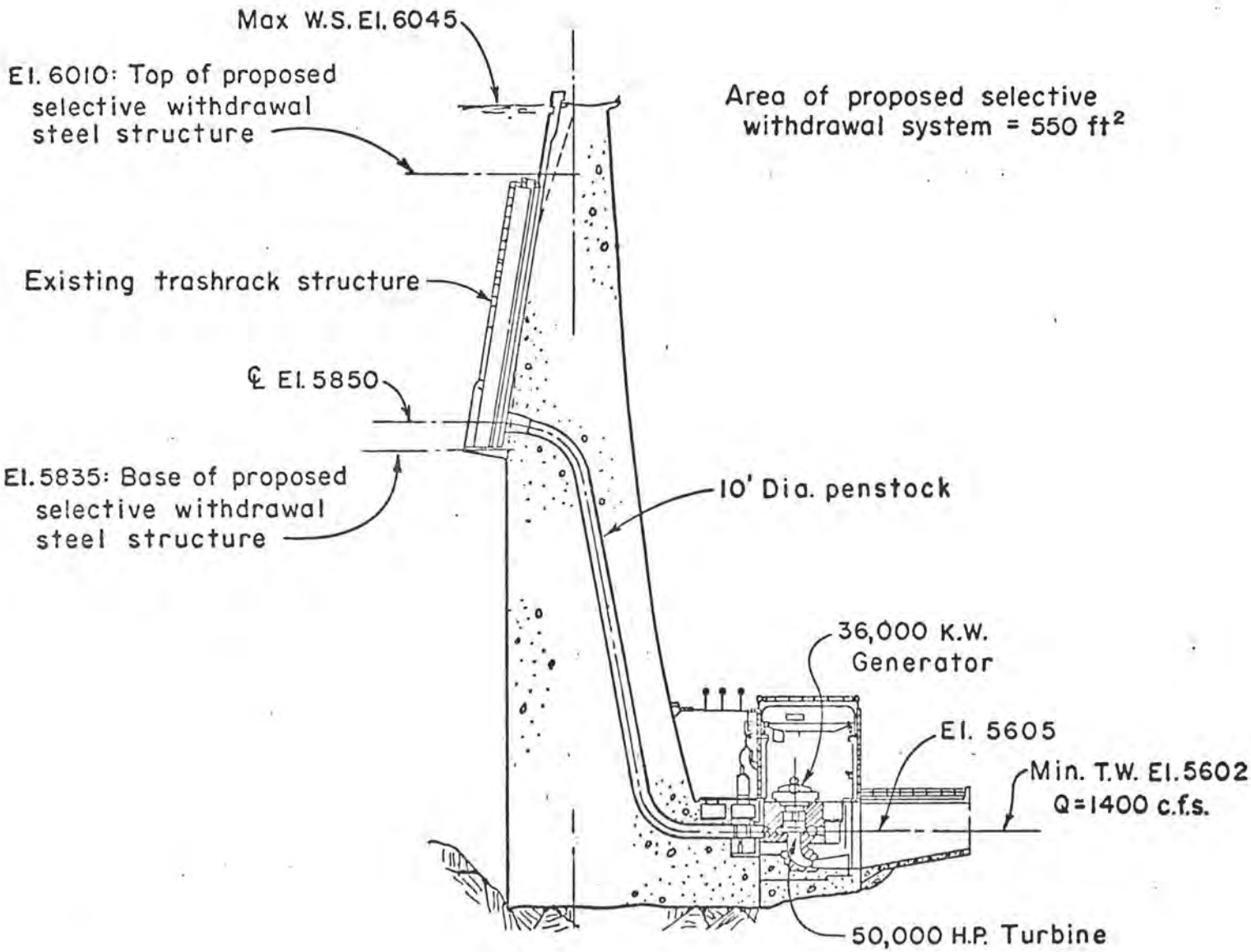
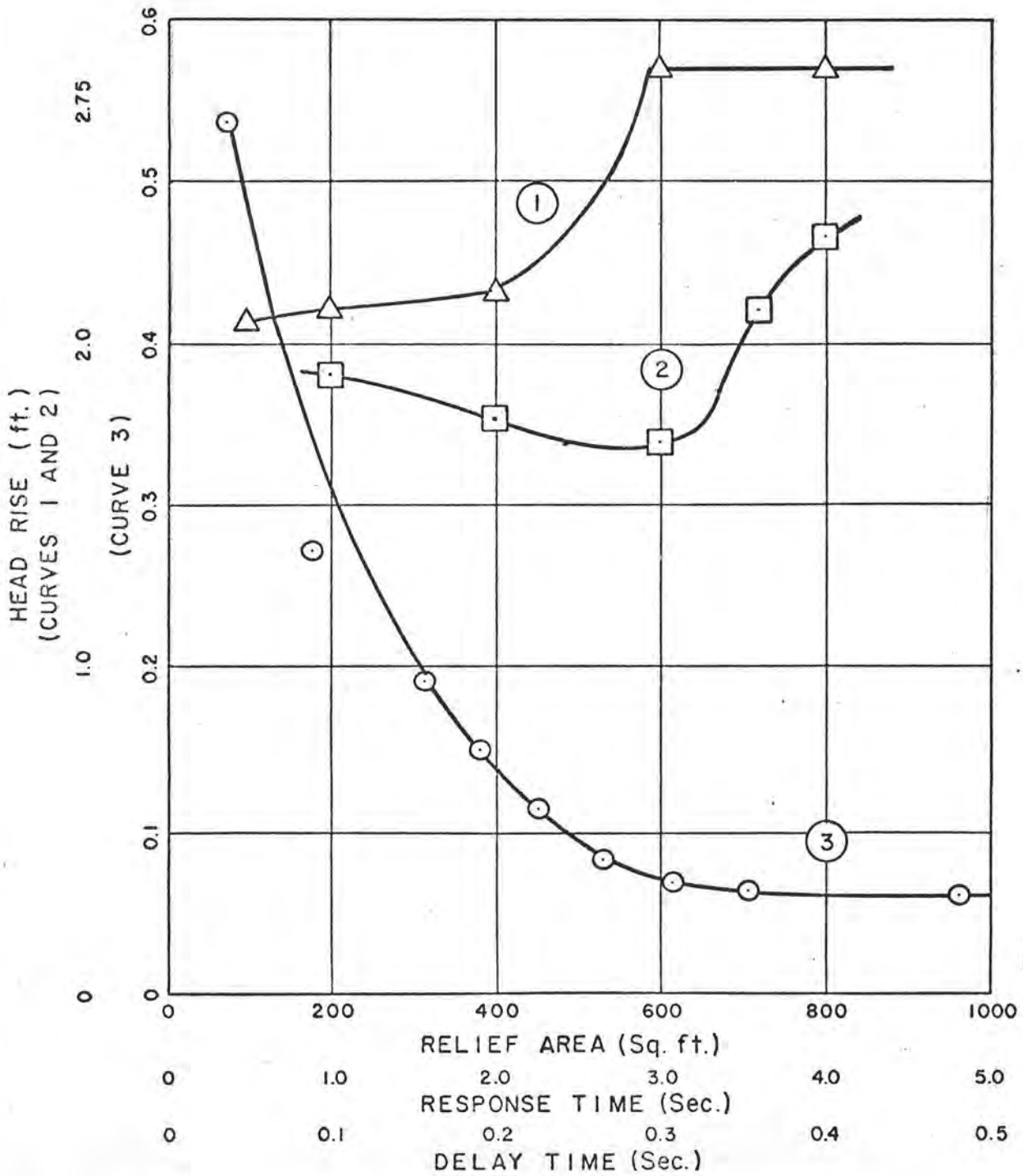


FIGURE I FLAMING GORGE DAM LOCATION OF PROPOSED SELECTIVE WITHDRAWAL SYSTEM



(1) Curve 1: Parameters are constant relief area of 78.5 SQ. FT. and a constant response time of 0.36 seconds while varying delay time from 0.05 to 0.4 seconds.

(2) Curve 2: Parameters are constant relief area of 78.5 SQ. FT. and a constant delay time of 0.1 seconds while varying response time from 1.0 to 4.0 seconds

(3) Curve 3: Parameters are increasing relief panel area with a zero delay and response time.
This is a limiting curve in that if a panel can be designed such that it's inertial characteristics are neglible, then the head rise would be given by this curve.

HEAD RISE IN THE FLAMING GORGE SELECTIVE WITHDRAWAL SYSTEM WITH RELIEF PANELS

FIGURE 2

significant since it indicates that if a panel can be developed such that it has a negligible response time and delay time, the water-hammer pressures in the selective withdrawal system can be reduced to very low values.

II. Problem Description

The existing inlet structure for the 10-foot-diameter penstock at Flaming Gorge Dam opens directly to the reservoir at elevation 5850 and discharges through the turbine at elevation 5605 (figure 1). Maximum water-hammer pressure rise, in this structure, occurs at the wicket gates and decreases linearly to zero at the penstock entrance. With a selective withdrawal system installed on the dam face, the overall length of the hydraulic circuit between the reservoir entrance and the wicket gates is increased (figure 3). With this increase in distance, three important changes occur.

A. The point of pressure relief originally at the penstock entrance will move to the selective withdrawal entrance.

B. The magnitude of water-hammer pressures in the penstock will increase.

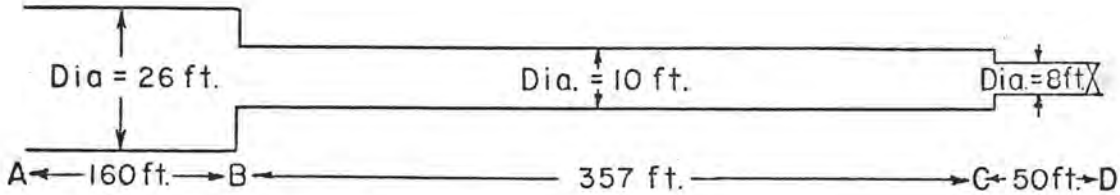
C. Water-hammer pressures will occur within the selective withdrawal area. Reduction of this pressure rise significantly decreases the structural requirements and results in a more economical design with lowered installation costs. This pressure reduction is affected by including relief panels into the withdrawal system as outlined in this report.

III. Selective Withdrawal System Design

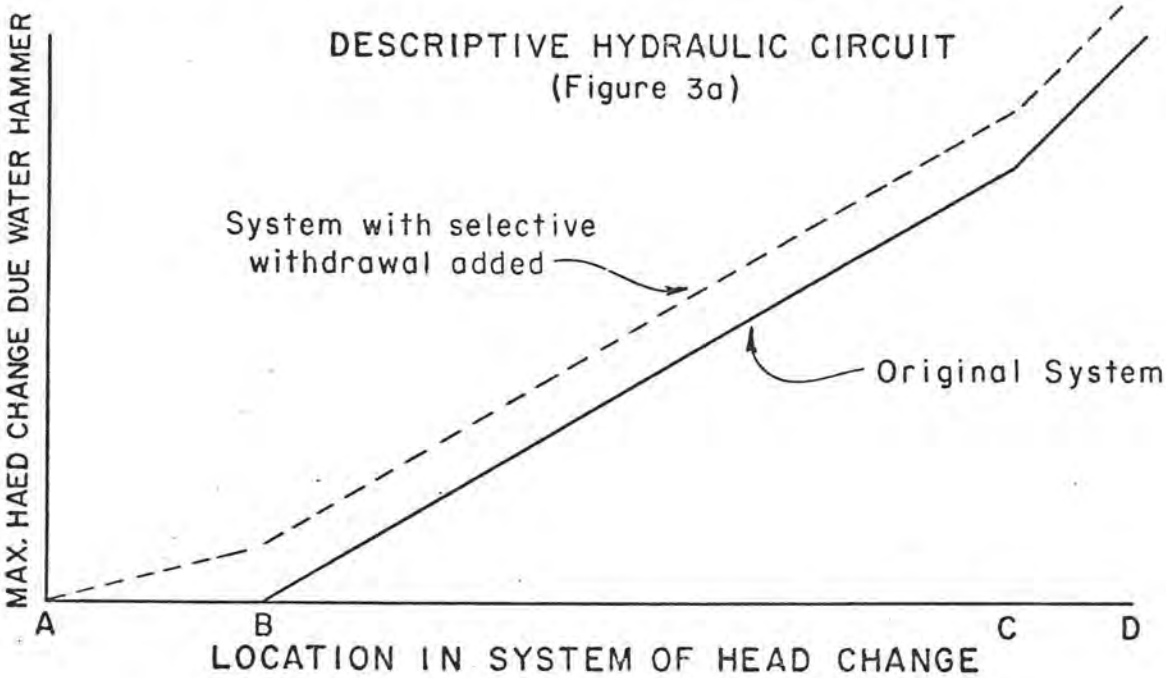
The Flaming Gorge selective withdrawal system (drawing No. 591-D-1396) is designed as a 3/16-inch plate steel rectangular structure, 25 feet wide, 20 feet deep, and 160 feet long, located between elevation 5835 and elevation 6010. This structure once in place would form both sides and the face while the dam itself would serve as the back side of the selective withdrawal system. Though the original trashrack structure would be left in place, it would not interfere significantly with the pressure waves and thus for water-hammer pressure determination, its presence could be ignored.

IV. Operating Conditions

In determining the condition that produces the most severe water-hammer pressures, the following conditions of operation were evaluated.



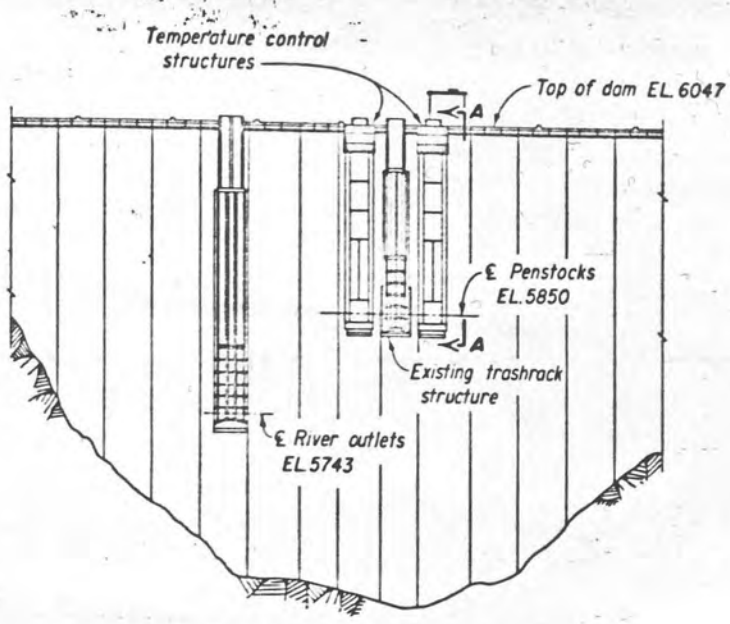
DESCRIPTIVE HYDRAULIC CIRCUIT
(Figure 3a)



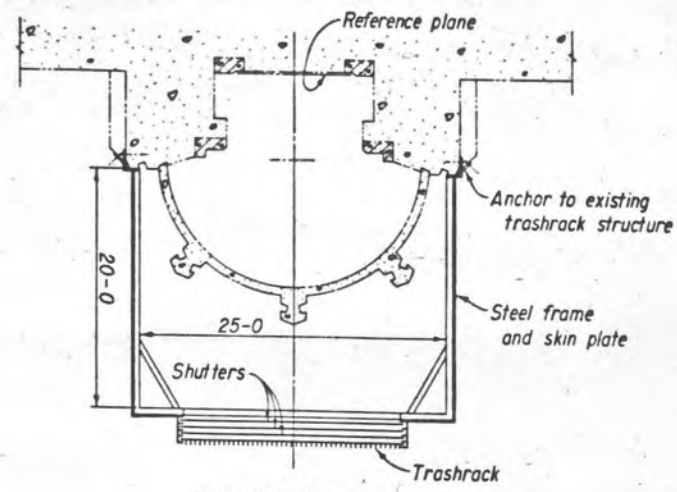
(Figure 3b)

The original hydraulic circuit started at point B (the penstock entrance) and ended at point D (the turbine wicket gates). The hydraulic grade line for this circuit would look like that of the solid line above. The hydraulic circuit with the Selective Withdrawal System added starts at point A (the Selective Withdrawal entrance) and ends at point D (the turbine wicket gates). The hydraulic grade line for this circuit would look like that of the dashed line above.

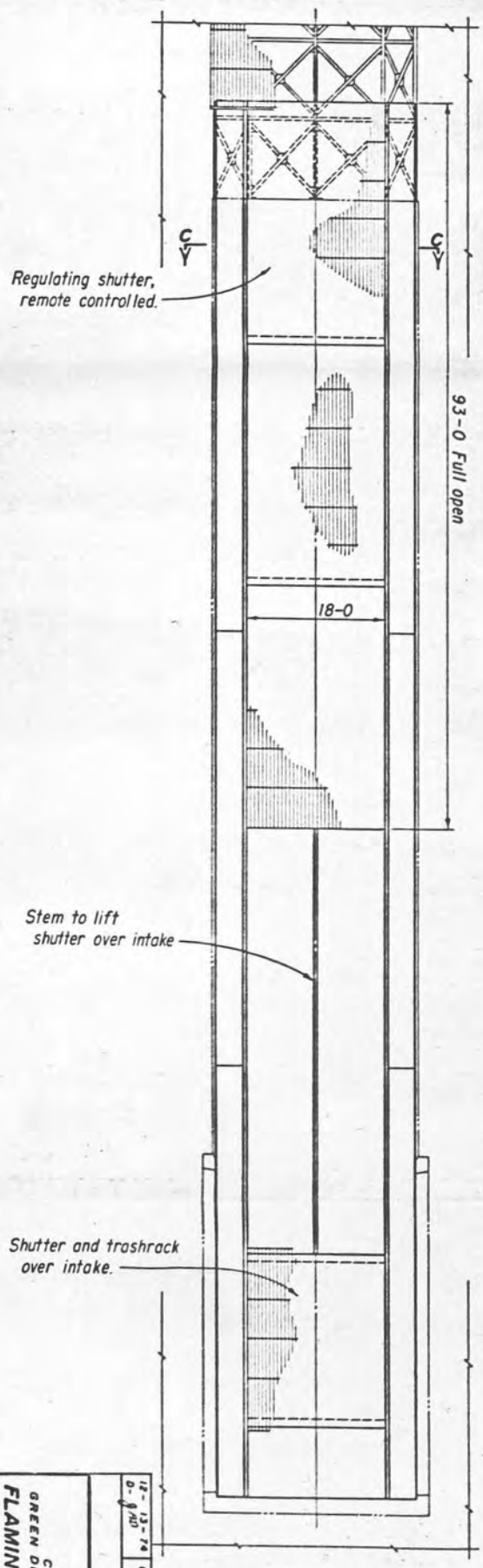
FIGURE 3



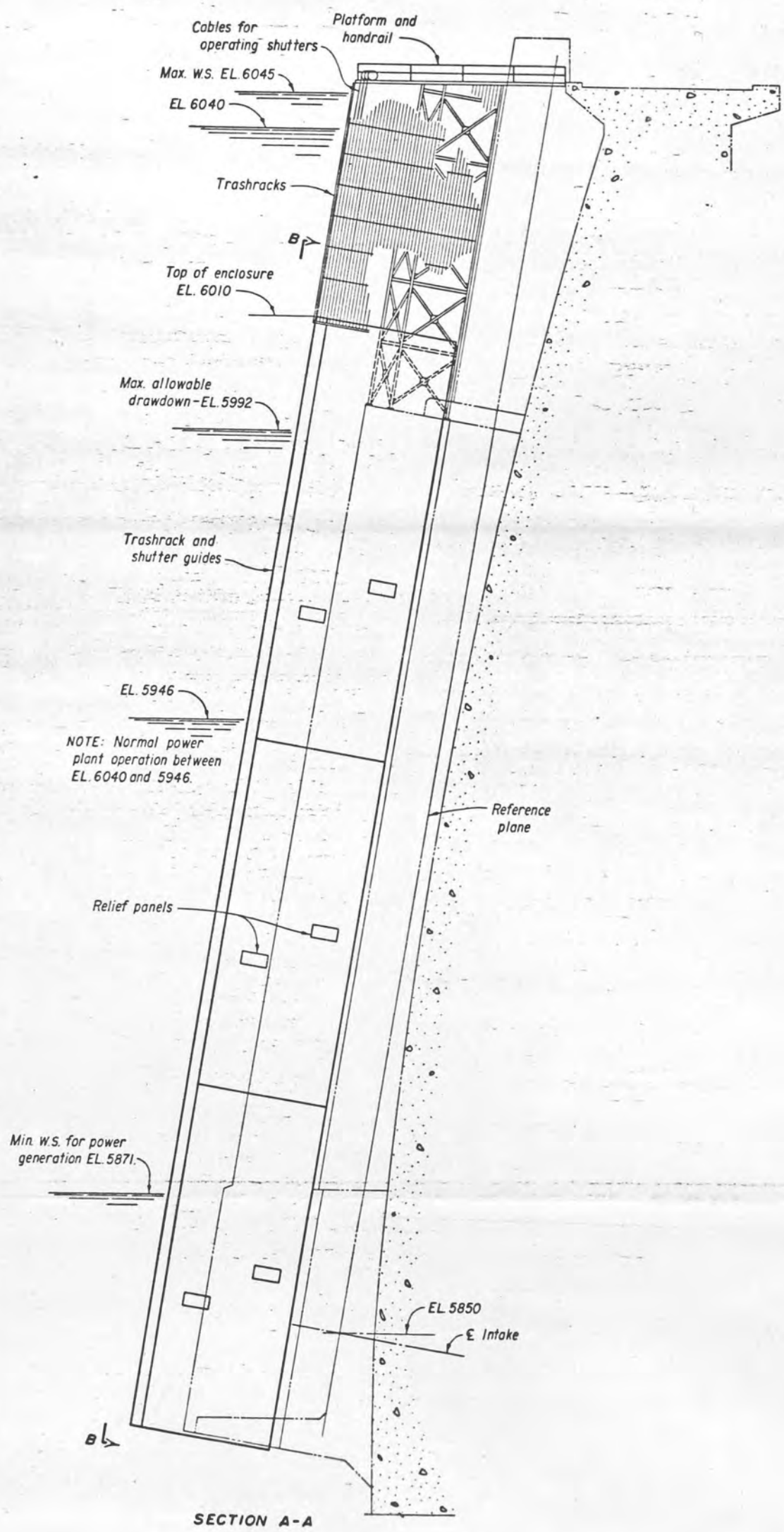
UPSTREAM ELEVATION



SECTION C-C



VIEW B-B



SECTION A-A

Preliminary estimated weight.....421,000

12-13-74 D-9 AD	CHANGED NOTE ON SECTION A-A AT EL. 6010

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT
GREEN DIV.-FLAMING GORGE UNIT--UTAH-WYOMING

FLAMING GORGE DAM AND POWER PLANT
TAILWATER TEMPERATURE CONTROL
INTAKE MODIFICATION
FEASIBILITY DESIGN DRAWING

DESIGNED ..... SUBMITTED .....
DRAWN ..... RECOMMENDED .....
CHECKED ..... APPROVED ..... CHIEF, DIVISION OF DESIGN

DENVER, COLORADO, APRIL 1, 1974

591-D-1396

A. Gate opening

B. Gate closing

C. Full gate flow at reduced head: $Q = 1{,}540\ ft^3/s; H = 410\ ft$

D. Maximum head at reduced flow: $Q = 1{,}450\ ft^3/s; H = 440\ ft$

E. Rate of gate closure or opening

From the conditions of operation (figure 4), it was determined that 100 percent head (440 ft) at reduced flow (1,450 ft^3/s) and a gate closure in 3.8 seconds (5.0 seconds from full gate), produced the most severe condition of operation. One-hundred percent head (440 ft) and 100 percent flow (1,540 ft^3/s) was not considered because of generator limitations. If a generator update is anticipated, then the increased flow, maximum head condition, would be a more severe condition of operation.

V. Water-hammer Analysis

For a selective withdrawal system with no provision for relief, the water-hammer pressures are a maximum at the base of the structure and decrease linearly to zero at the system entrance (elevation 6010). With a full gate closure time of 5 seconds, the maximum pressures experienced are +7.09 and -8.28 feet occurring at 6.1 and 4.0 seconds, respectively (figure 5). After complete gate closure, the pressure oscillates rapidly with an amplitude of 7.5 feet and a period of 0.4 second.

By installing relief panels in the selective withdrawal system, water-hammer pressures can be reduced. The amount of relief available is largely dependent upon:

A. The available relief area. For maximum effect, the relief area should be placed close to the point of disturbance. In this case the disturbance occurs at the wicket gates and the closest relief point is the base of the selective withdrawal structure.

B. How quickly the relief panels open. This is dependent upon the design and geometry of the relief panel. In this study only the effects of various delay and response times were studied.

A relief system having 78.5 square feet of panels at elevation 5850 that starts to open 0.3 second after gate closure initiation and is completely open 3.6 seconds later, reduces maximum pressures to

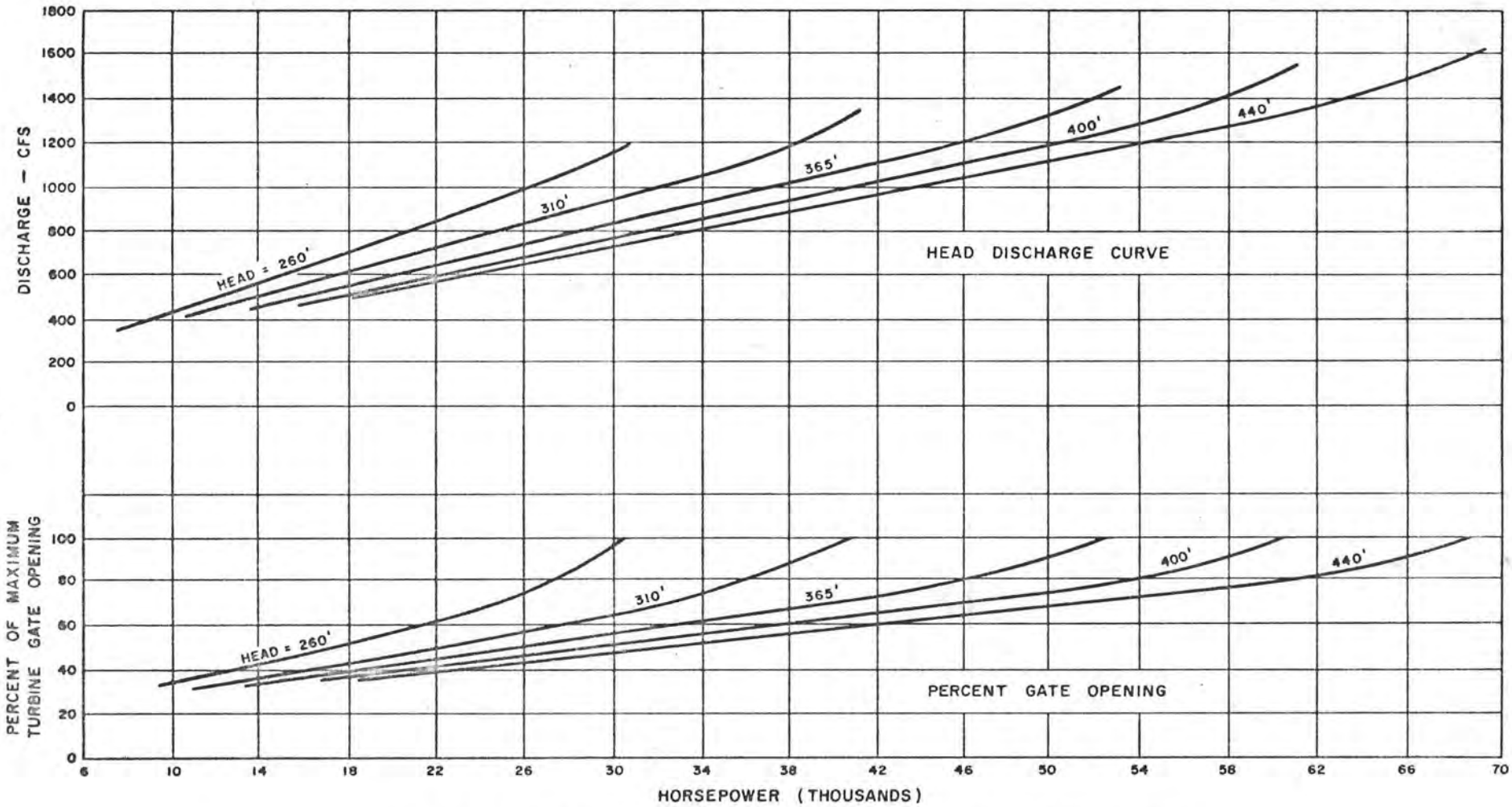


FIGURE 4 - TURBINE CHARACTERISTICS (FLAMING GORGE DAM)

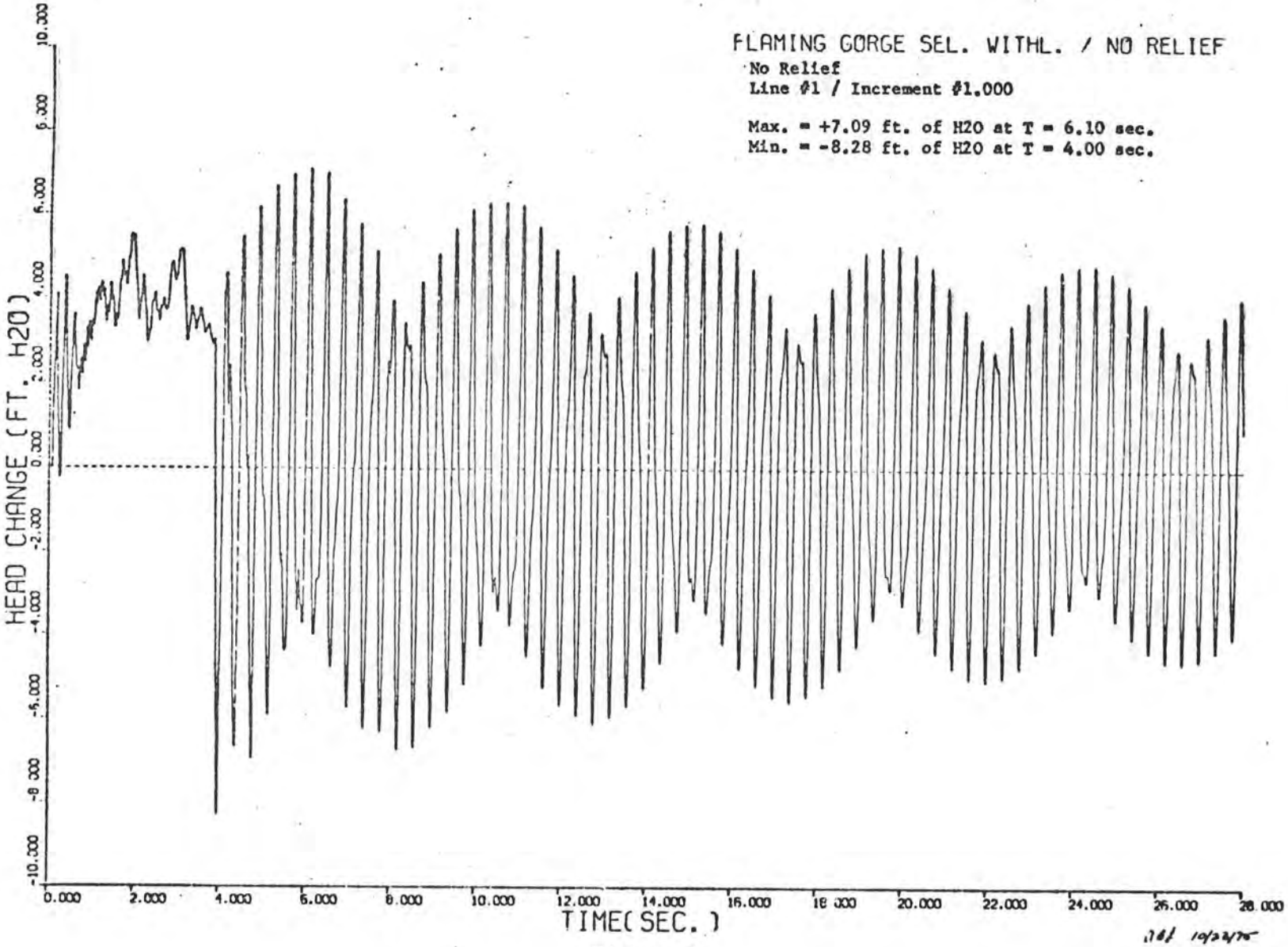


Figure 5

Head Rise at Base of Selective Withdrawal System With Zero Relief

+2.85 and -0.00 feet of water at 0.28 and 0.09 second, respectively (figure 6). The large oscillations that occurred in the no-relief system, after complete gate closure, are practically eliminated.

By increasing the relief area (figure 7), the previous pressure maximum occurring at 0.31 second does not change. However, the pressure amplitudes occurring after this maximum are reduced sharply. As can be seen in figures 6 and 7, the pressures prior to complete gate closure are reduced to 0.95 foot. Pressures after complete gate closure are also reduced by an equivalent amount.

Modifying the relief system such that there is less delay time (figure 8) before the start of relief panel operation eliminates the peak that occurs at time = 0.31 second. Elimination of this peak will reduce the maximum positive pressure to +2.11 feet in a system with 78.5 square feet of relief area. A maximum positive pressure of +0.95 foot can be achieved by a system with 177 square feet of relief area. In both systems the maximums occur at 1.99 seconds.

Further modification in the relief system, such that an instantaneous response is possible, could achieve greater reductions of water-hammer pressures. A system with 78.5 square feet of relief panel area responding instantaneously (figure 9) can maintain water-hammer pressures at the base within +0.35 foot at 4.11 seconds and -0.32 foot at 3.91 seconds. However, due to the extremely fast response with this system (figure 10), water-hammer pressures are maximum at the two-thirds length with pressures of +0.54 and -0.51 foot of water at times 4.22 seconds and 4.29 seconds, respectively. As with the no-relief system there is the presence of the rapid pressure oscillations. These oscillations damp out with time and are greatly reduced from those in the no-relief system. As indicated by table 1 and figures 11, 12, 13, and 14, further increase in relief area will reduce pressures to well below one-half foot of water in both the positive and negative ranges.

The computations for this report were performed by the writer by adapting the Bureau's hydraulic transient computer program to this problem. Mr. Don McKean supervised the studies and performed check calculations.

Comments

Within the scope of this report, delay time and response time are defined as follows:

> Delay time is the time required for the relief system to start its response once the fluid transient condition has been initiated.

Response time is the time required for the relief system to provide the total area of relief to the transient condition. The percent effective relief panel area provided is assumed to be linear with time.

As can be seen from figure 2, to achieve good results from the relief system, the panels should start to open within 0.2 second, be fully open within 3.0 seconds, and provide a relief area of 700 square feet.

Relief Area (sq. ft.)	Waterhammer Pressure (ft.)	Time (sec.)	Elevation
78.5	+0.35 / -0.32	4.11 / 3.91	5850
78.5	+0.54 / -0.51	4.22 / 4.29	5914
177	+0.14 / -0.17	4.21 / 3.91	5850
177	+0.27 / -0.24	4.11 / 4.03	5914
314	+0.09 / -0.11	4.10 / 3.97	5850
314	+0.19 / -0.14	4.11 / 4.03	5914

TABLE 1

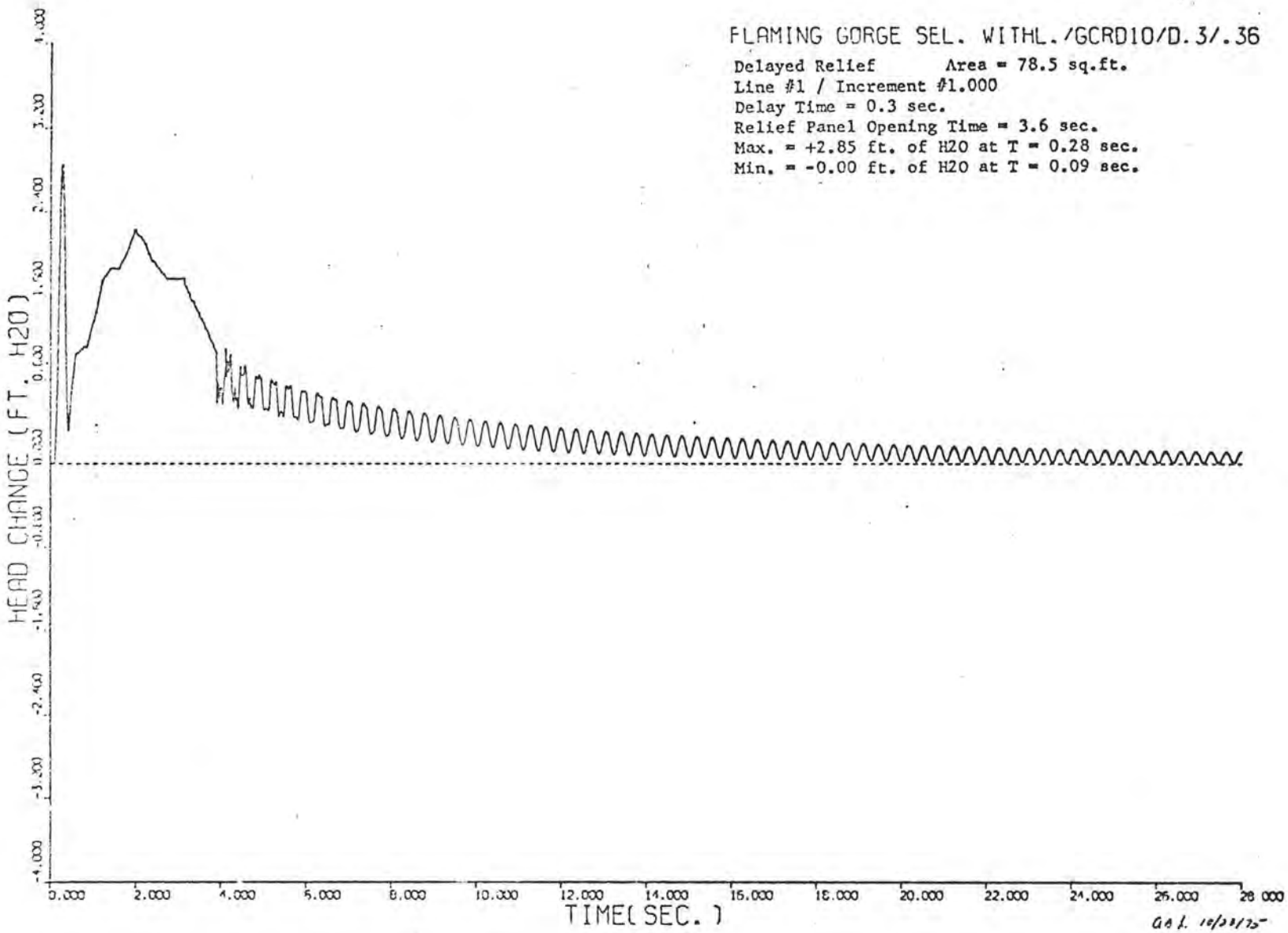


Figure 6

Head Rise at Base of Selective Withdrawal System With Delayed Relief

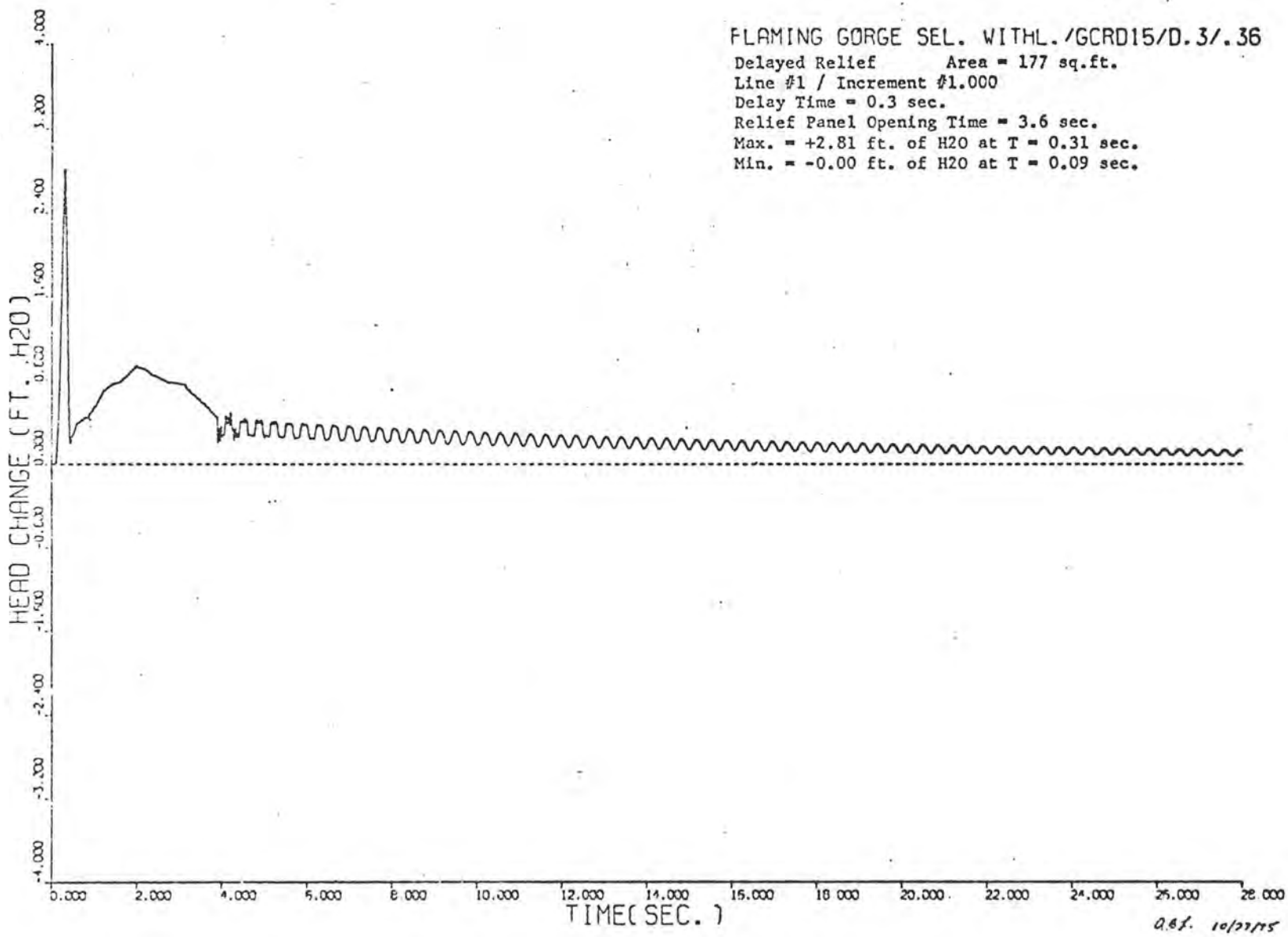


Figure 7

Head Rise at Base of Selective Withdrawal System With Delayed Relief

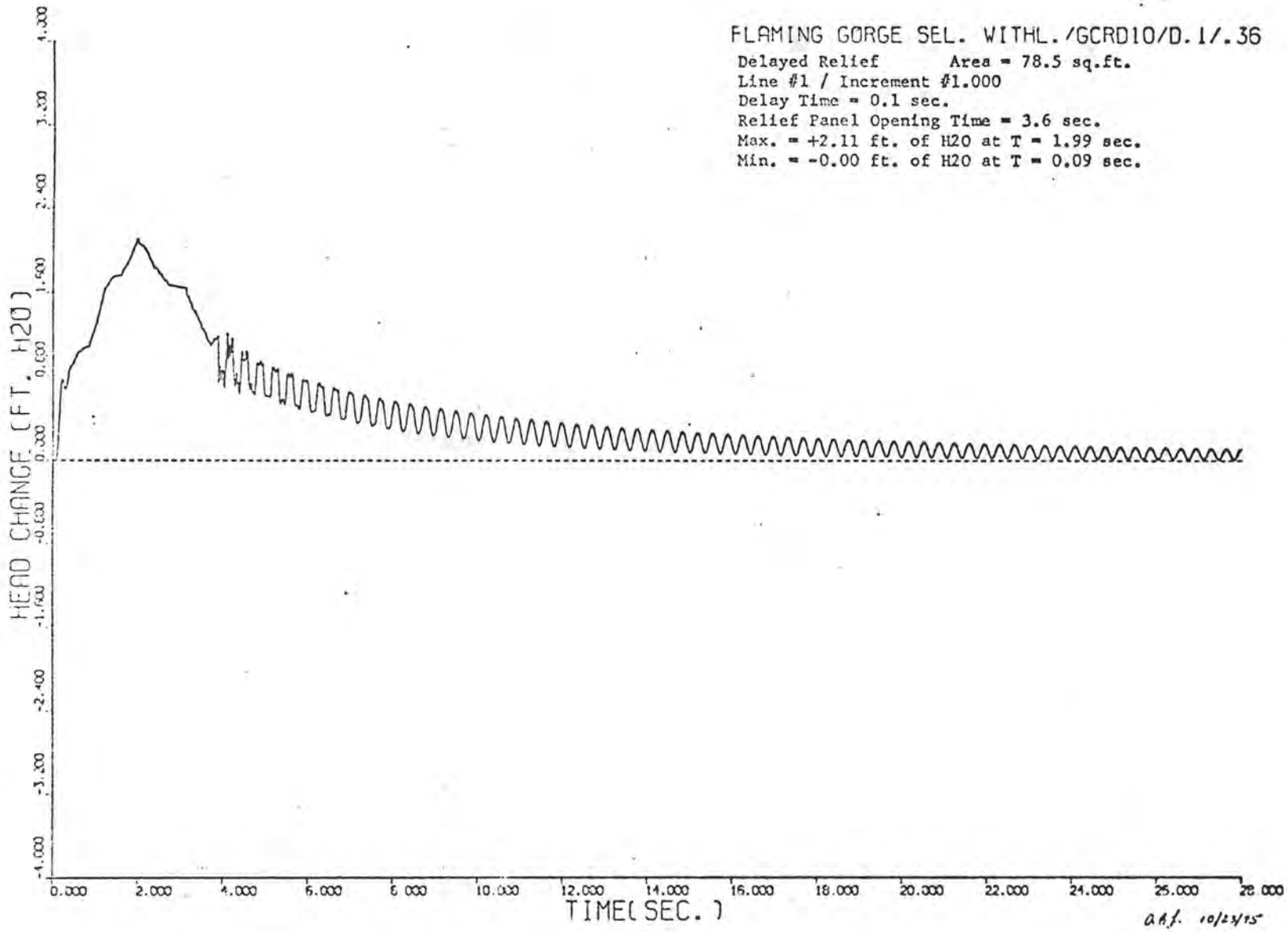


Figure 8

Head Rise at Base of Selective Withdrawal System With Delayed Relief

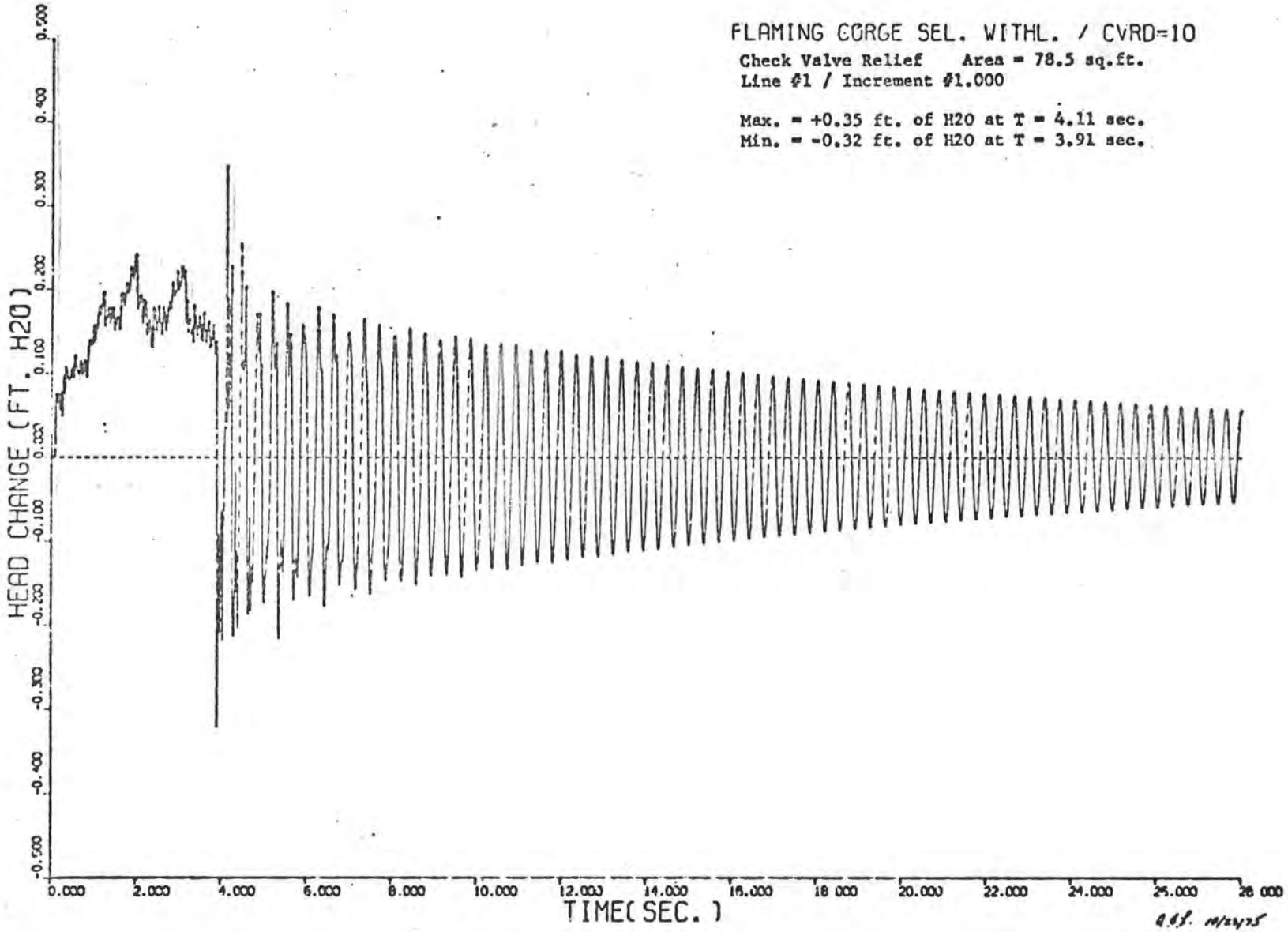


Figure 9

Head Rise at Base of Selective Withdrawal System With Instantaneous Relief

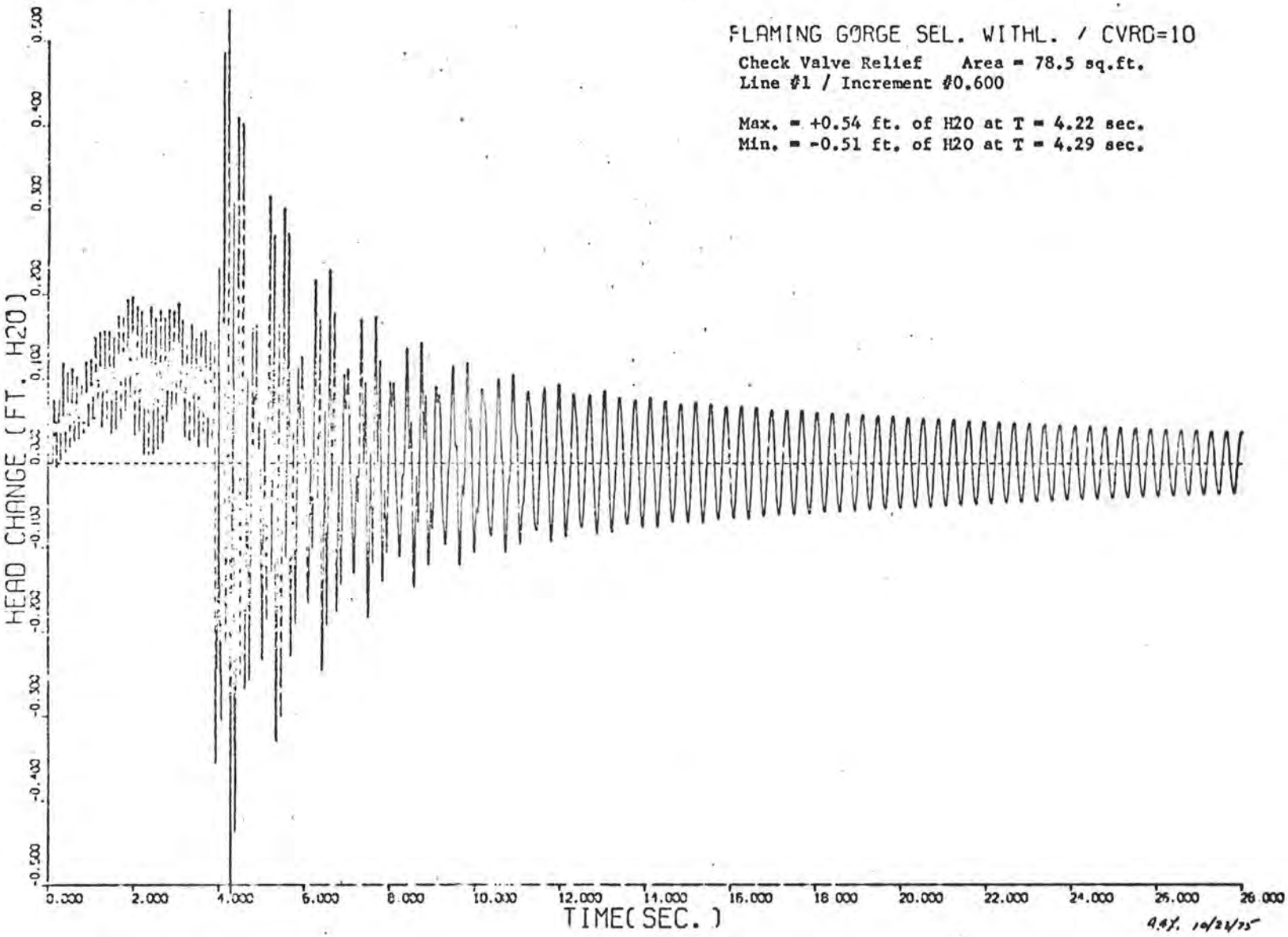


Figure 10

Head Rise at Elavation 5946 on the Selective Withdrawal System With Instantaneous Relief

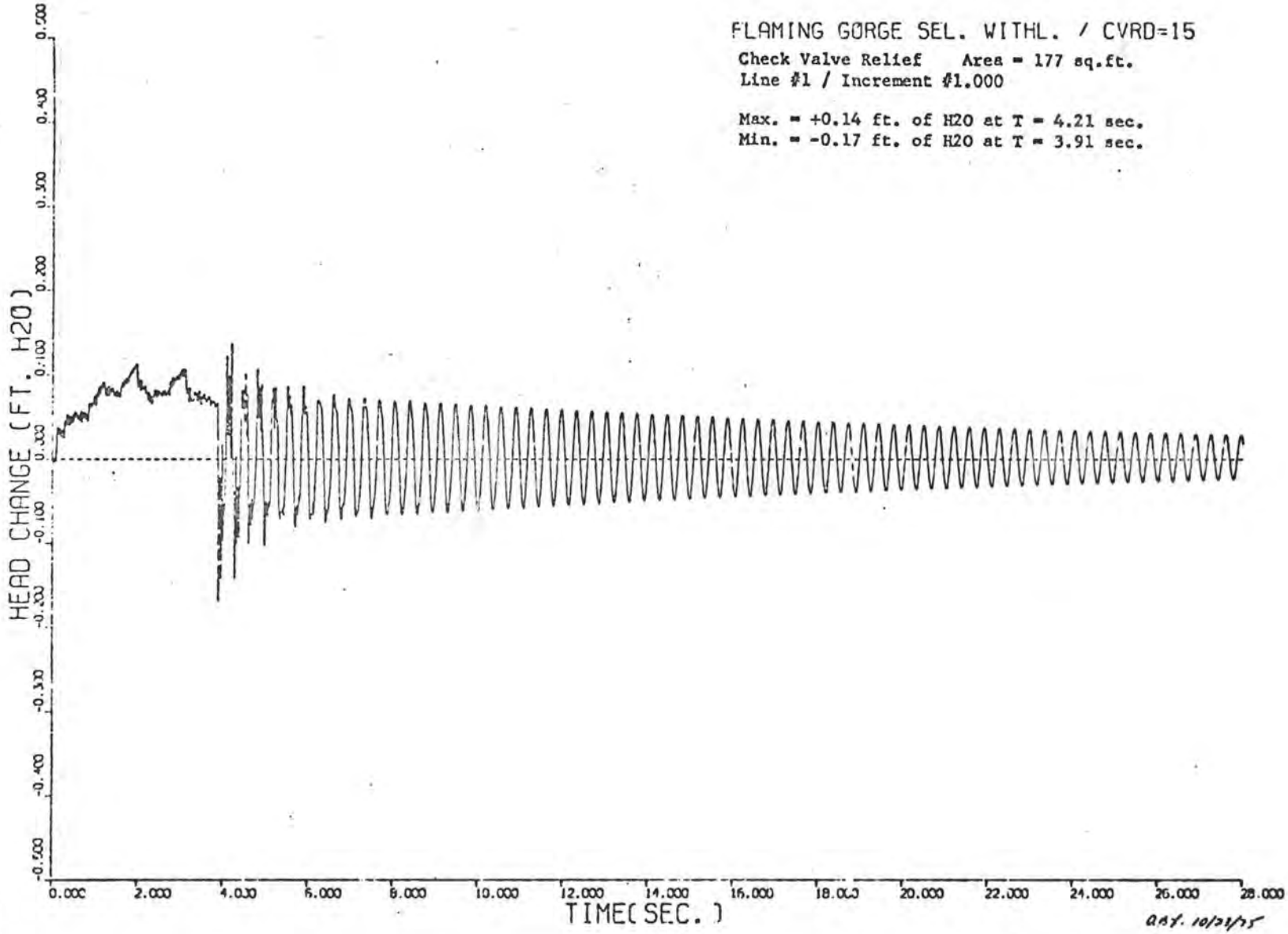


Figure 11

Head Rise at Base of Selective Withdrawal System With Instantaneous Relief

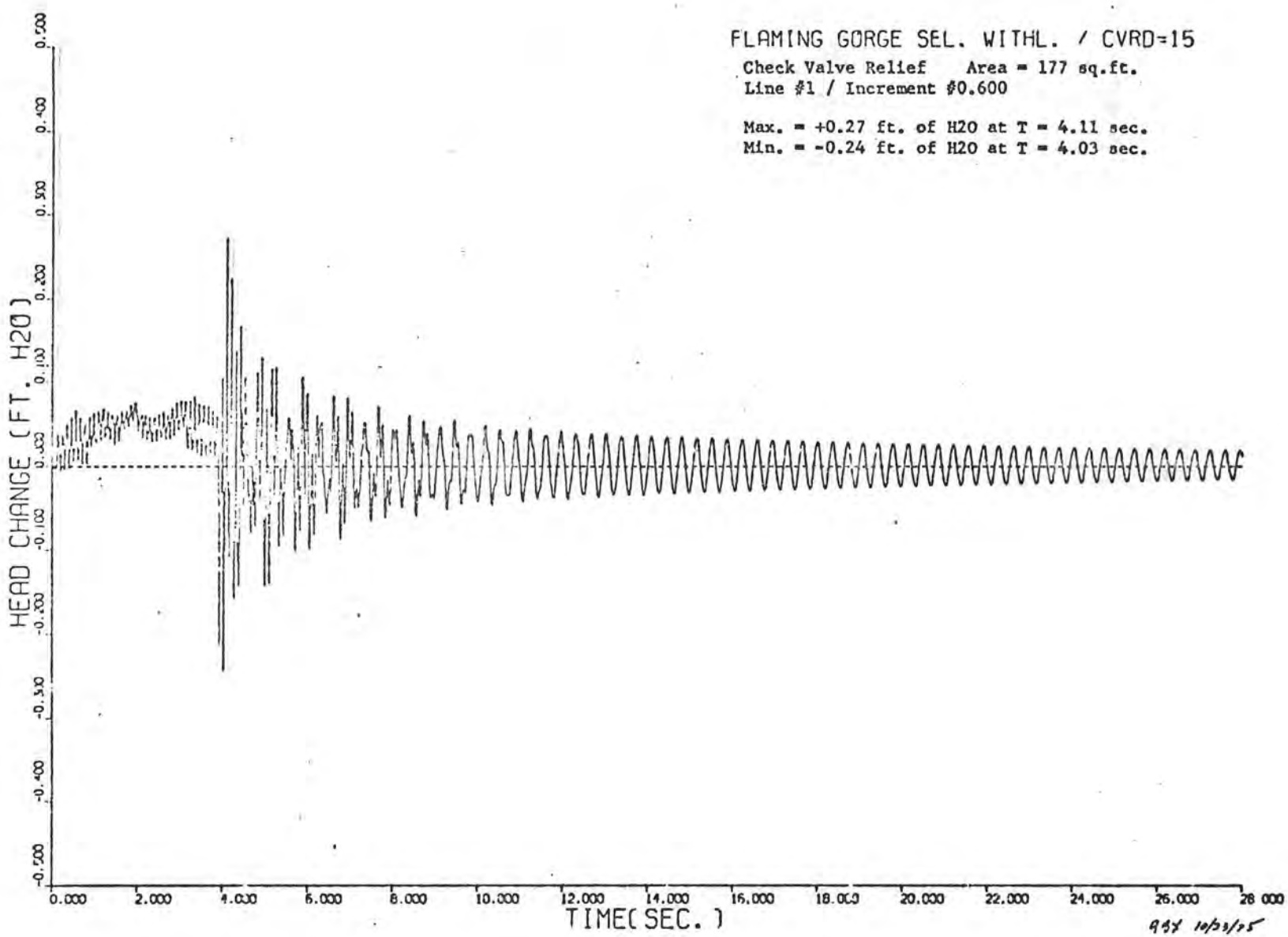


Figure 12

Head Rise at Elavation 5946 on the Selective Withdrawal System With Instantaneous Relief

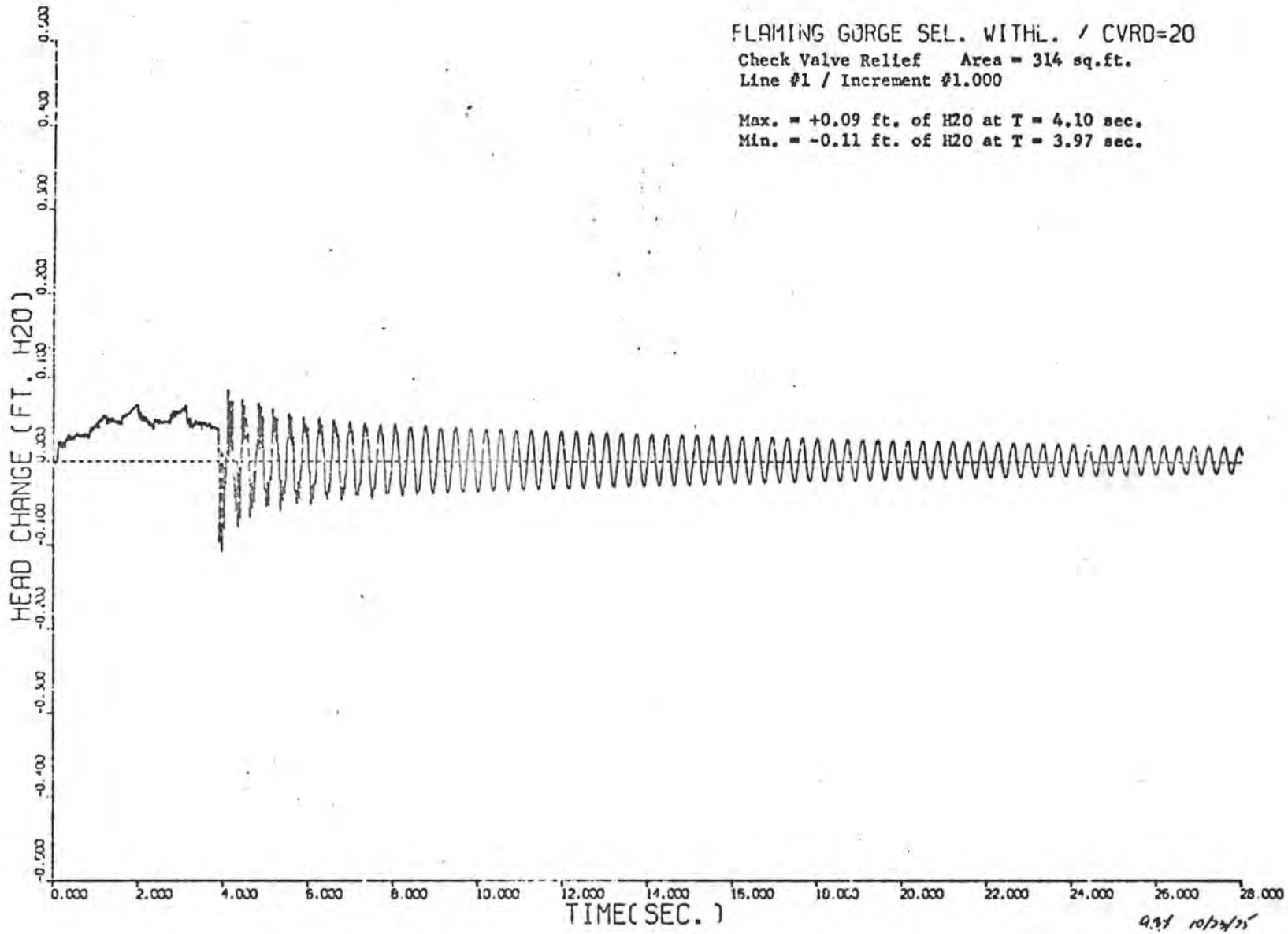


Figure 13

Head Rise at Base of Selective Withdrawal System With Instantaneous Relief

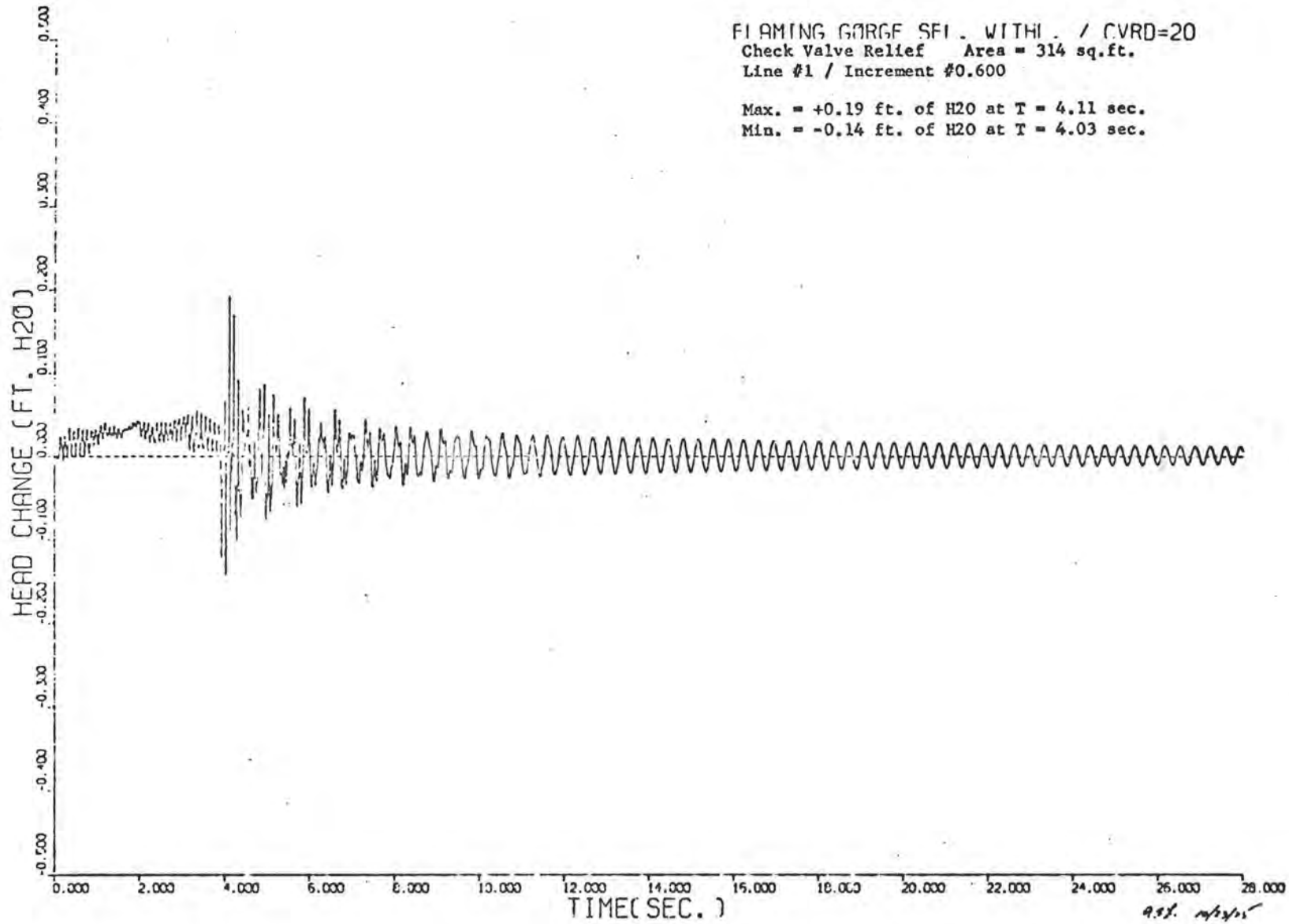


Figure 14

Head Rise at Elavation 5946 on the Selective Withdrawal System With Instantaneous Relief

References

(1) Memorandum dated August 11, 1975, from D. B. Mountjoy, Head Gates and Valves Section, Mechanical Branch, Division of Design, Bureau of Reclamation, Denver, Colorado

(2) United States Department of Interior, Bureau of Reclamation Drawing No. 591-D-1396, Intake Modification Feasibility Design Drawing

(3) James Leffel Company Manufacturer's data curve 2512, dated April 20, 1962, for Department of Interior, Bureau of Reclamation Flaming Gorge Powerplant

(4) United States Department of Interior, Bureau of Reclamation Hydraulic Turbine Data, Flaming Gorge Powerplant

(5) United States Department of Interior, Bureau of Reclamation Drawing No. 591-D-165, Flaming Gorge Dam Penstocks - Plan and Profiles - Steel Pipe

(6) United States Department of Interior, Bureau of Reclamation Hydraulic Turbine Acceptance Test, Flaming Gorge Powerplant, Report HM-7 dated January 1967

(7) United States Department of Interior, Bureau of Reclamation Designer's Operating Criteria, Flaming Gorge Dam, Powerplant, and Switchyard, dated November 1963

(8) State of California, Department of Water Resources Technical Memorandum No. 11, dated April 1965, Oroville Powerplant Intake Structure

(9) State of California, Department of Water Resources Report No. Hyd-549, Hydraulic Model Studies of the Pressure Relief Panels in the Powerplant Intake Structure - Oroville Dam - California