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UNITED STATES
DEPARTMENT OF THE INTERIOR
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HYDRAULIC LABORATORY REPORT NO. 191

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HEAD LOSSES IN BUTTERFLY VALVES

ESTES PARK POWER PLANT - COLORADO BIG THOMPSON PROJECT

By

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Denver, Colorado

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Branch of Design and Construction
Engineering and Geological Control
and Research Division
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Hydraulic Laboratory

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Reviewed by: J. W. Ball

Subject: Head losses in butterfly valves - Estes Park Power Plant - Colorado Big-Thompson Project.

INTRODUCTION AND SUMMARY

Butterfly valves have been installed frequently immediately upstream of turbines to shut off flow in the penstock when the turbine is not in operation. An installation of this type does not require regulation of flow with the valve; consequently, the leaf is in either the open or closed position.

Since many of these valves are used in conjunction with the generation of power, the head losses through them are of primary importance. Previous field tests of the butterfly valves installed at Boulder Dam have indicated losses through the valve amounting to approximately 38 percent of the penstock velocity head. While this amounts to only 1.33 feet for a total head of approximately 550 feet, the value of this additional head in terms of power is appreciable, especially in large units.

A considerable amount of thought and effort has been directed towards reducing the loss through butterfly valves. Towards this end, a particular design was evolved (figure 1). It consists of a revolving leaf of a simpler shape than the conventional type, placed between two stationary vanes, which have the effect of streamlining the leaf when it is in the open position, reducing the turbulence caused by the blunt edges of the conventional leaf and increasing the efficiency of the valve. As this design was new, information concerning the relative merits of the conventional and new design was lacking, so the problem of determining the characteristics of the valve was given to the hydraulic laboratory.

The laboratory study consisted of aerodynamic tests to determine the difference in head loss between the conventional and the new leaf. These tests showed a loss of 21.2 percent of the penstock velocity head for a conventional leaf as compared to 18.6 percent for the new leaf, or a saving of 2.6 percent, which when converted to head, amounts to approximately 0.10 of a foot of water with a penstock velocity of 15 feet per second.

TEST EQUIPMENT

The different butterfly valve leaves were tested with air as the fluid medium. The accuracy and practicability as well as the time-saving features of this method of testing have been well established and will not be discussed here.

The equipment consisted of a Roots blower with a 3-1/2-inch orifice on the intake. The discharge was through a 4-inch line connected to the 5-inch sheet metal conduit which formed the upstream end of the model. The valve was constructed of sheet metal with a wooden replica of the leaf fixed stationary in the full open position. A 36-inch length of pipe was placed downstream from the valve and piezometers were located as shown in figure 2.

Pressure measurements to determine the volume of air passing through the model were made with a vertical water manometer. Measurement of the piezometer pressures was with an inclined water manometer calibrated to read directly in feet of air pressure.

TEST PROCEDURE

The blower used in these tests was a displacement type which delivered slightly more than the 6 cu. ft. of air per second under atmospheric conditions. In conducting the tests, the blower was started about 15 minutes before actual testing to allow the temperature of the various parts of the apparatus to stabilize. During the warm-up period the gages were carefully zeroed.

The first test consisted of placing the new leaf (leaf 1, figure 2) in the apparatus and obtaining the pressure at the piezometers as well as that across the orifice. This procedure was repeated several times, and identical readings were obtained in each case. By computing the volume of air passing through the system and applying Bernoullis' theorem, the losses were obtained. Immediately following this test and without disturbing the settings of the gages, leaf 1 was replaced by leaf 2 and the process repeated. As before, the gage readings were identical for consecutive runs with this leaf.

On some installations on the Missouri Basin Project, it was planned to use butterfly valves incorporating the design of leaf 1, figure 2, and because of circumstances peculiar to some installations, the valve was to be close coupled between an upstream bend in the penstock and the turbine scroll case. It was generally conceded that the knife edges of the stationary vanes were desirable when the approach velocity was uniform throughout the flow. However, other experimenters have shown that the upstream knife edge is not desirable and that any advantage gained by streamlining might be lost if the approach flow is turbulent and the velocity is not uniform. Such a condition would exist in the Missouri Basin Projects where the penstock elbow was near the valve. It has been found that under these circumstances it is desirable to have the upstream vane rounded instead of sharp. This causes less eddy motion and helps reduce turbulence in the flow.

To determine if rounding of the upstream vane would have any measurable effect on the head losses through the valve in the model, leaf 1 was altered to leaf 3 (figure 2) and the testing procedure of the previous tests repeated. These tests did not show any increase in loss over those with the sharp-edged vanes.

RESULTS

The losses with the three types of leaves were based on the pressures at piezometers 2a and 4 because piezometer 2a was the minimum pressure upstream of the valve and piezometer 4 was the maximum in all three cases. The pressure at piezometer 3 was consistently lower than that at 4. This was due to the contraction at the entrance to the straight section of pipe.

The loss with leaf 1 in place was found to be 18.6 percent of the velocity head in the pipe upstream of the valve. The corresponding loss with leaf 2 was 21.2 percent, or 2.6 percent more than leaf 1. This represents a very small difference in the head loss when it is considered that the maximum velocity head in the penstock usually does not exceed 3.5 feet.

The loss with leaf 3 in the valve was the same as that obtained for leaf 1. There was no attempt made to place a bend in close proximity to the valves to determine the effect of the rounding of the vane on the losses when the approach flow was not rectilinear. The fact that there was no increase in head loss in rectilinear flow was considered sufficient evidence to recommend the rounding when the approach flow is turbulent.

In view of the fact that the pressures at piezometer 4 were consistently higher than those at piezometer 3, it seems probable that increased performance can be obtained from an installation if a pipe length of one diameter is placed between the valve and the turbine scroll case.

As a matter of record, the piezometric pressures in feet of air for the three types of butterfly leaves are shown in tabular form below.

	Air Discharge C.F.S.	1a	2a	3	4	5	6	7
Leaf 1	6.07	70.2	69.2	14.5	17.0	16.0	14.0	3.5
Leaf 2	6.07	70.2	69.1	14.7	17.1	16.0	14.0	3.5
Leaf 3	6.07	71.9	71.0	17.5	18.0	16.0	14.5	3.5

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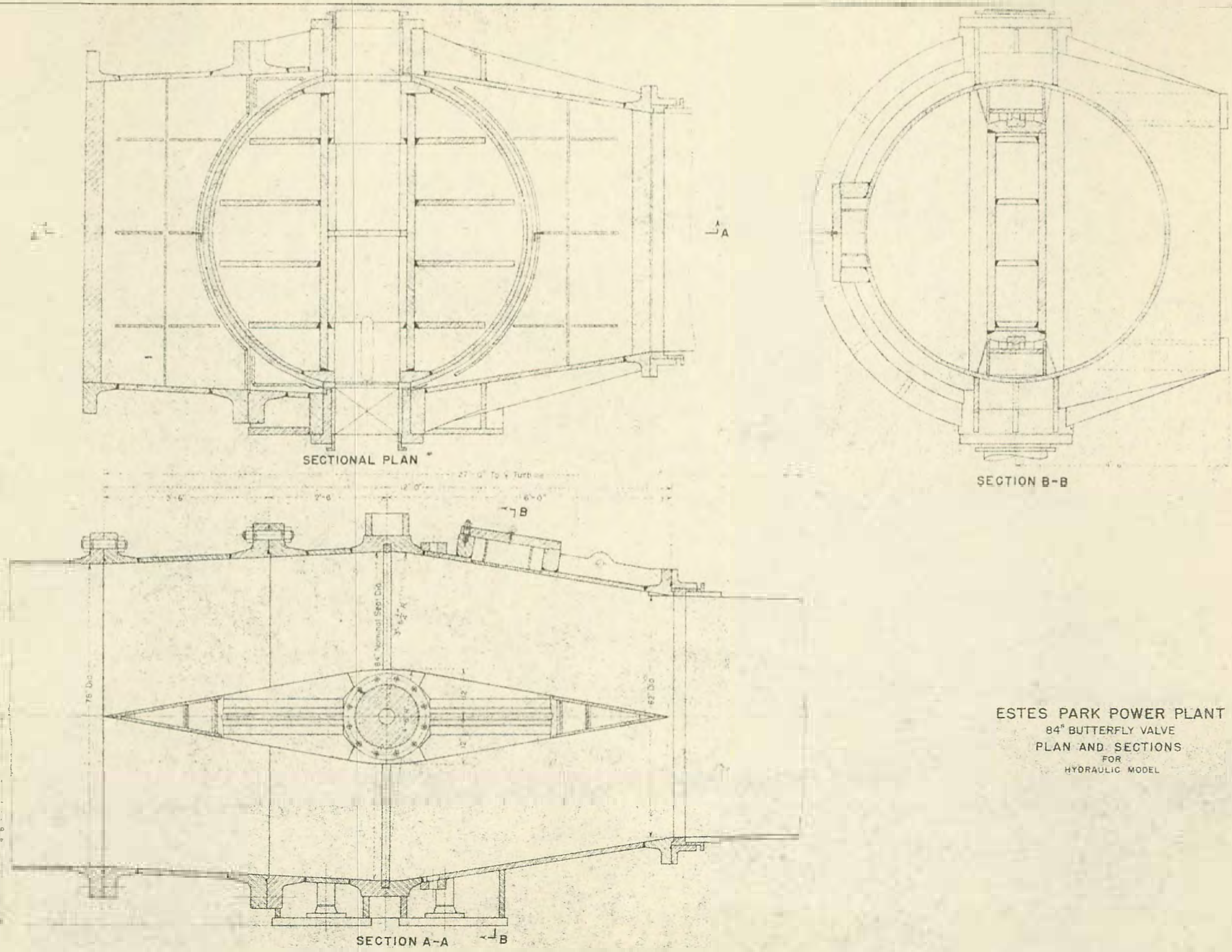
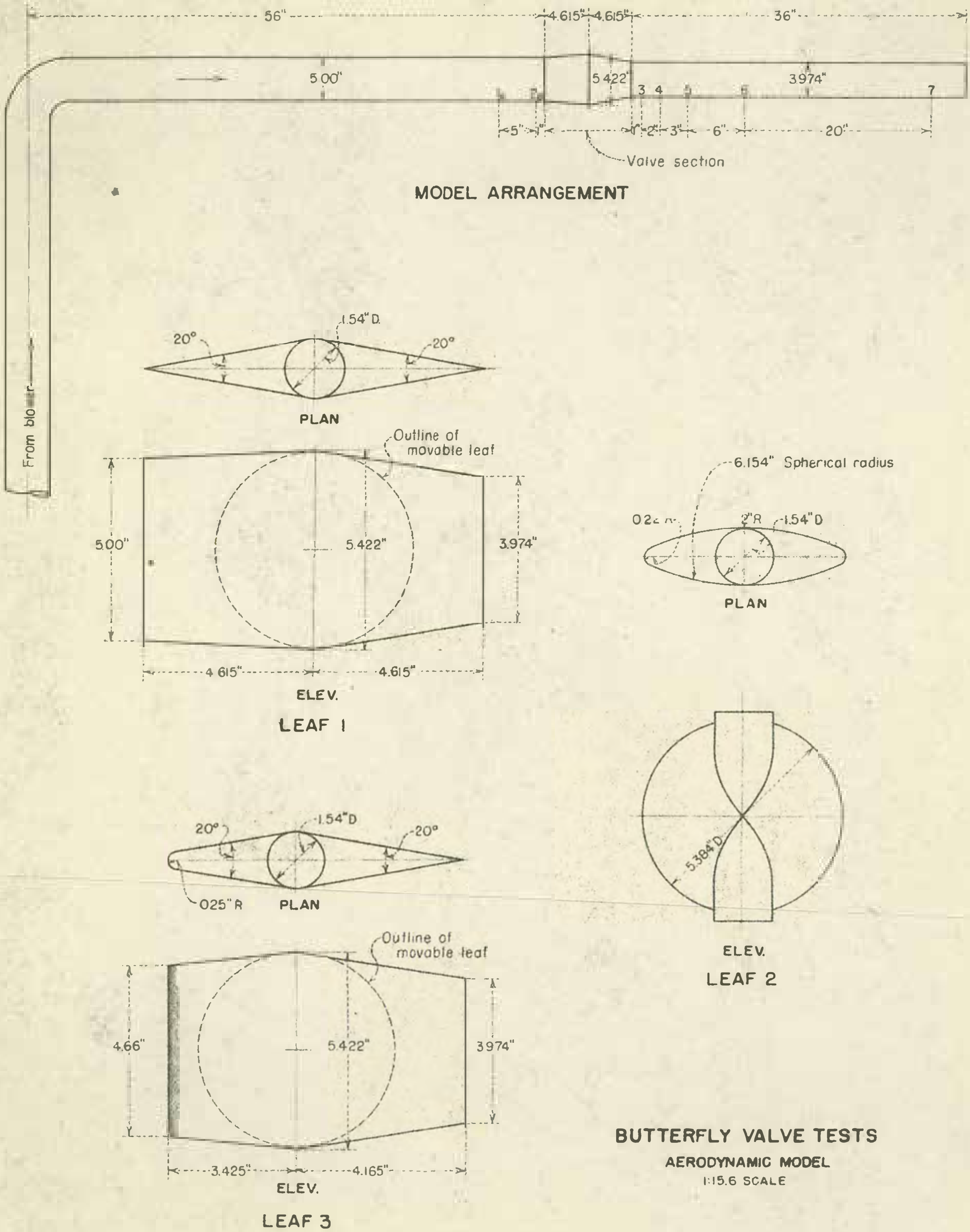


ESTES PARK POWER PLANT
84" BUTTERFLY VALVE
PLAN AND SECTIONS
FOR
HYDRAULIC MODEL

FIGURE 1

FIGURE 2



BUTTERFLY VALVE TESTS

AERODYNAMIC MODEL

1:15.6 SCALE