PAP-1010

Grand Coulee Turbine and Draft Tube Studies

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United States
Department of the Interior
Bureau of Reclamation
Denver, Colorado
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GRAND COULEE TURBINE AND DRAFT TUBE STUDIES

The generating units proposed for installation at Grand Coulee Dam will be the largest ever built. Each unit will have an output of 150,000 horsepower when operating at best efficiency and discharging 4,400 cubic feet per second under the normal head of 335 feet. The ultimate installation includes 18 units, three of which will be installed at present and the remainder as additional power requirements arise. The generators, which will be direct-connected to the turbines, will be rated at 130,000 kilovolt-amperes.

Since turbine design has reached its present state of refinement, an important factor in the over-all efficiency of the installation is the draft tube. In the case of Grand Coulee the average velocity at the exit from the turbine runner for a discharge of 4,400 cubic feet per second will be 27.0 feet per second, which corresponds to a velocity head of 11.3 feet. As draft tubes are generally only about 75 percent efficient, the velocity head actually recovered is something like 8.5 feet, or 2.5 percent of the normal head on the turbine. An improvement of 10 percent in draft tube efficiency would therefore result in an increase of 0.25 percent in the over-all efficiency of the units. It was decided that this possible improvement justified a model study.

Preliminary studies of draft tube designs were made using small wooden models set in an open tank. The flow from a turbine runner was simulated by means of vanes which imparted a whirl to the water entering the draft tube model. From these studies three designs were selected as the most promising for final studies. In making the final selection, which is shown on one of the attached drawings, it was felt that it would be necessary to have the draft tube in its proper setting below a turbine runner. Therefore a model turbine was constructed to a scale of 1:24 and the final selection was made on the basis of the efficiency of this turbine with the draft tube attached.

The model turbine was designed and constructed by the laboratory personnel. It develops approximately 1-3/4 horsepower with a head of 14 feet and a discharge of 1-1/3 cubic feet per second. The penstock, scroll case, and draft tube were molded from transparent pyralin to

afford visual inspection of flow. The speed ring, gates, and runner were cast in "Government genuine babbitt" and are held in their respective positions by a bronze casting. This bronze casting is the only part of the turbine made outside the laboratory. The turbine shaft is connected to an Alden-type hydraulic brake and also through speed-increasing gears to the rotor of a 3-phase, 220-volt motor which serves as a dynamometer. The entire torque from the stationary elements of both brake and motor, with the single exception of the friction in a large ball bearing, is registered on a scale beam which is balanced by movable weights. The output is limited to such a value that the motor always operates at synchronous speed so that the turbine speed is maintained at a constant value. A cross section of the turbine and dynamometer is shown on an attached drawing.

Water is supplied by an 8-inch centrifugal pump to a pressure tank from which it flows through the model turbine and draft tube to a steel tail-water box, then to a weir box where the discharge is measured over a 2-foot rectangular suppressed weir. Photographs of the model installation are shown on the attached plate.

Because of the interest in the model construction displayed by visitors, several aspects of its construction will be discussed. As previously stated, the penstock, scroll case, and draft tubes were made of colorless, transparent pyralin, a plastic that can be molded when heated to a temperature of approximately 115 degrees centigrade. The penstock and draft tubes were made in halves by pressing the pyralin between a mold and a form. The scroll case, however, was formed by drawing the pyralin over a form without a mold. This was quite an undertaking because of the complicated shape of the scroll. The speed ring, gates, and runner were cast in babbitt because this metal is easy to machine or carve and has a low melting point. The gates were die-cast successfully by allowing the die to cool from the bottom up. This procedure allows molten metal from the top to replace the space left by contraction of the metal below as it cools. The runner and speed ring were cast in an iron mold with cores of dental plaster to form the vanes. These cores were cast in the mold with detachable iron rings in place to serve as upper and lower shrouds. Photographs of the iron molds and the plaster cores are shown on the attached plate. Smooth, accurate castings were obtained by this method.

With a model turbine available, other phases of the turbine and its installation were investigated. Paint tests were made on the runner and speed ring. These were accomplished by painting the parts to be studied with white lead and then operating the model for about ten minutes. The water flowing over the painted parts leaves streak lines which indicate the direction of flow. Several shapes of fair-water cones were tested for their effect on turbine efficiency. The use of a splitter in the throat of the draft tube to prevent surging was also investigated. Since it was possible that the penstock elbow just upstream from the turbine might have an adverse effect on the efficiency, this feature was also studied.

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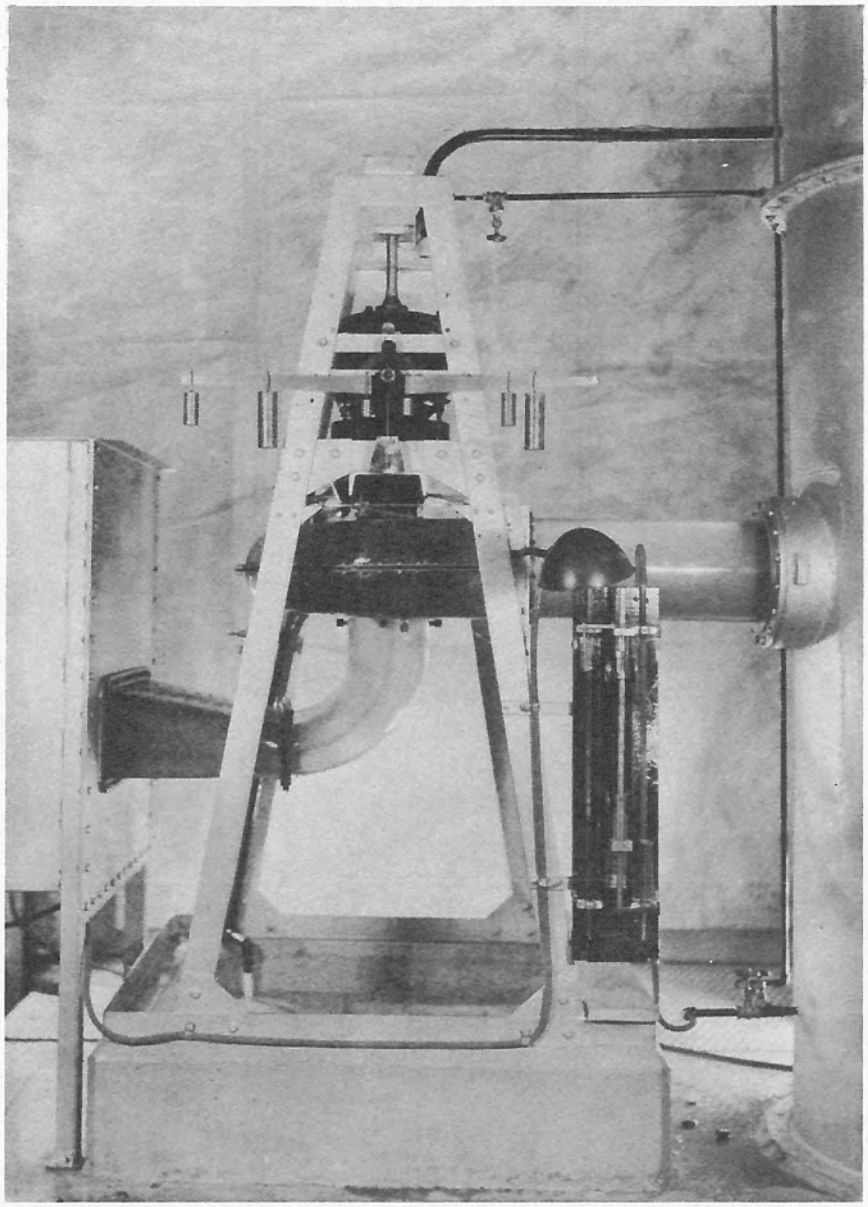
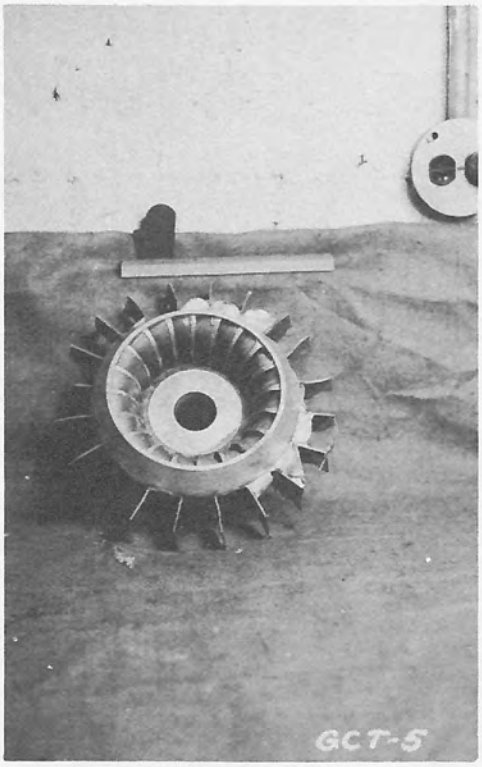
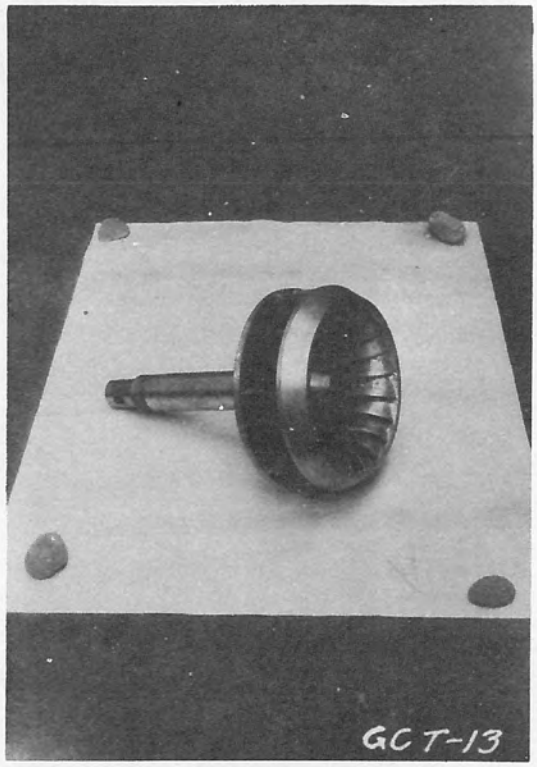


TURBINE MODEL OPERATING

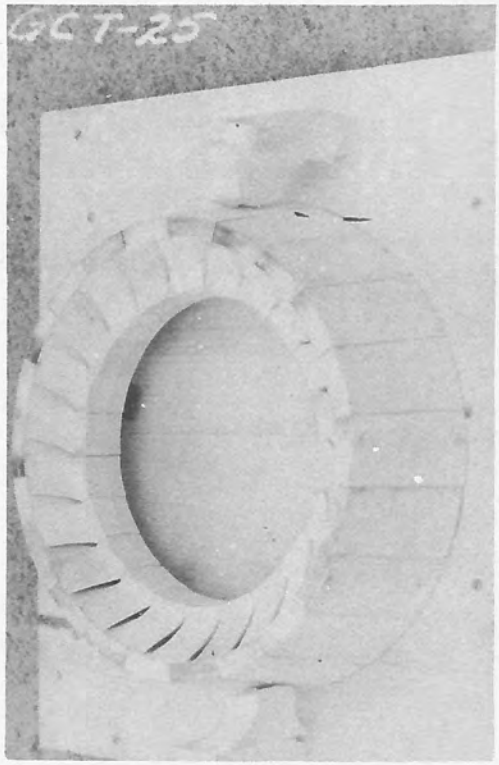
RUNNER MOLD



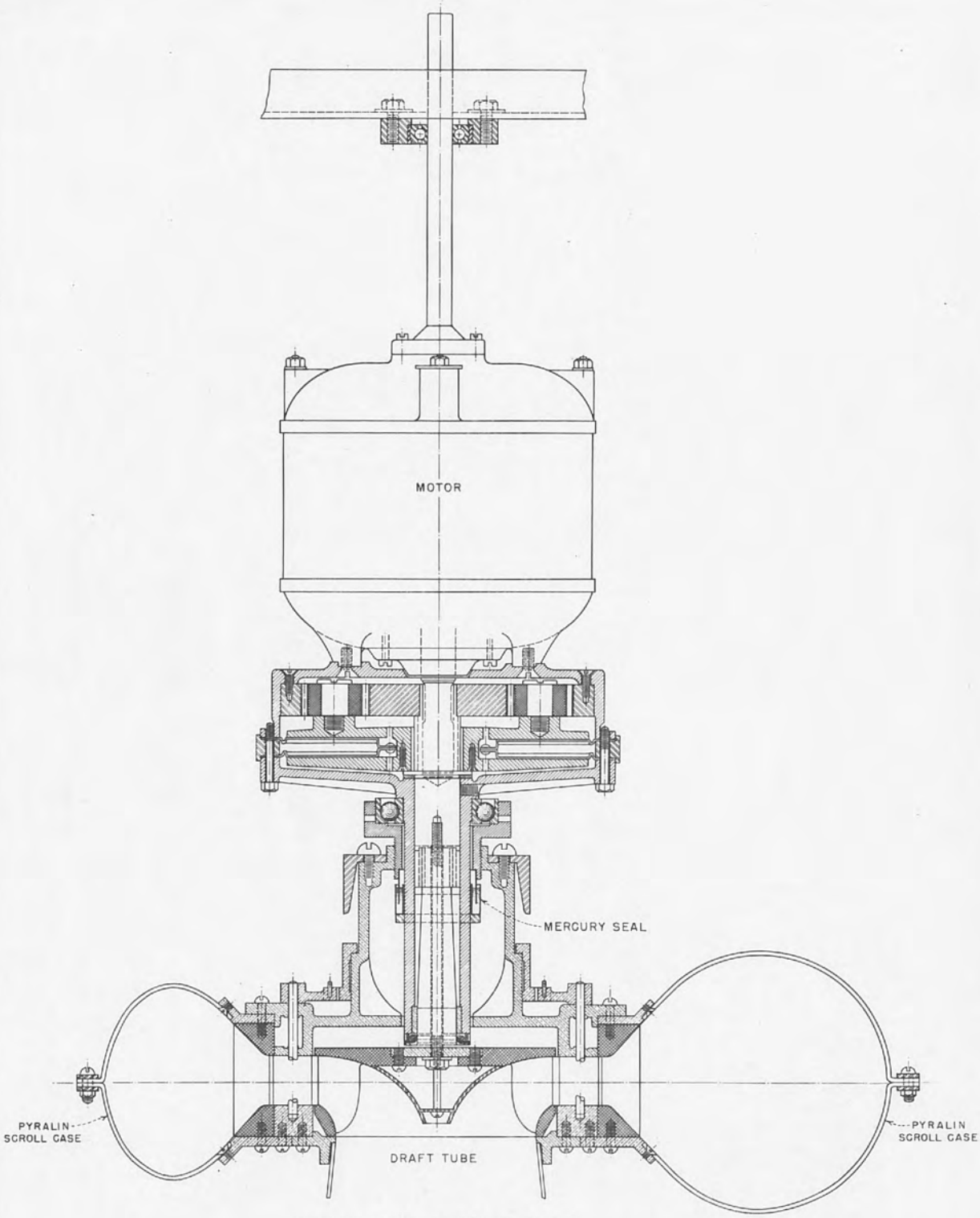
RUNNER JUST OUT OF MOLD



FINISHED RUNNER



SPEED RING MOLD



SECTION THRU TURBINE MODEL

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT-WASHINGTON

GRAND COULEE DAM

HYDRAULIC MODEL STUDIES
TURBINE ASSEMBLY

DRAWN E.S.G.-D.A.W. SUBMITTED
TRACED C.A.-D.R.S. RECOMMENDED
CHECKED APPROVED

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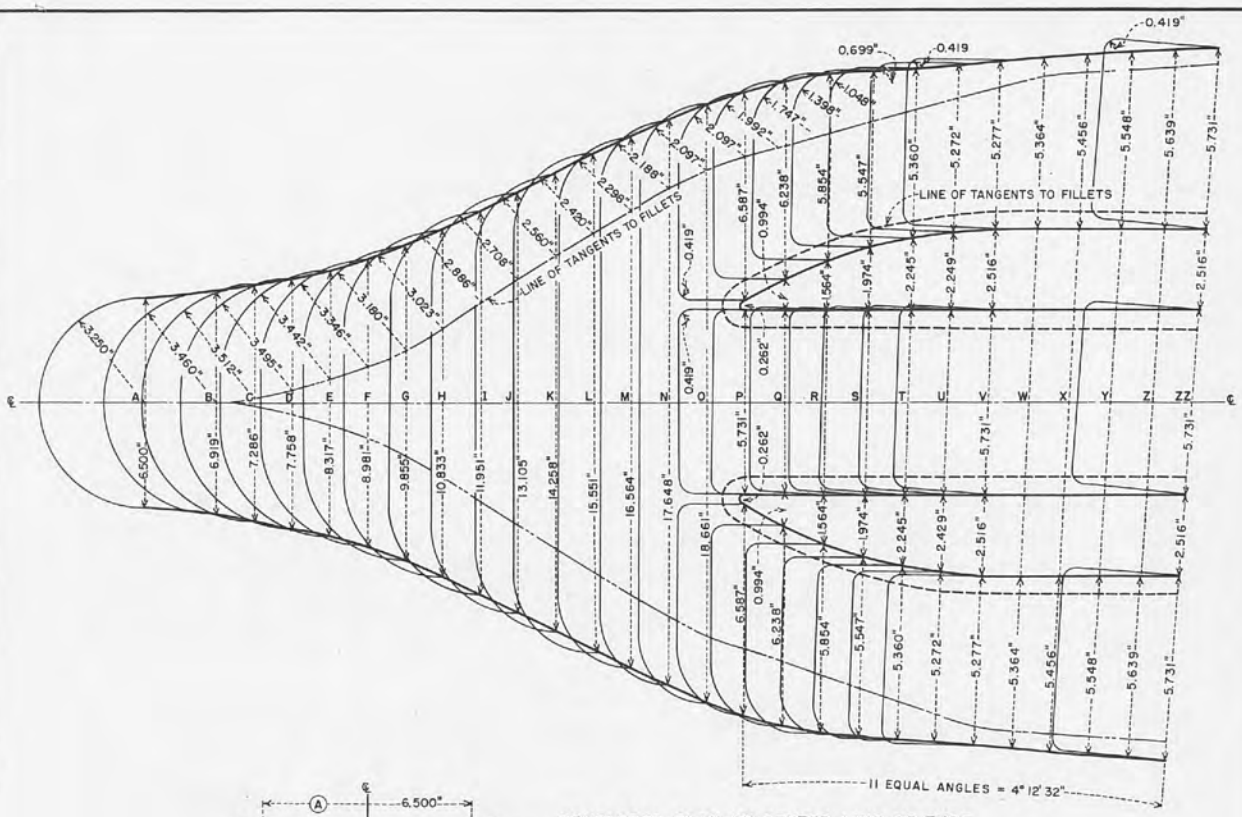
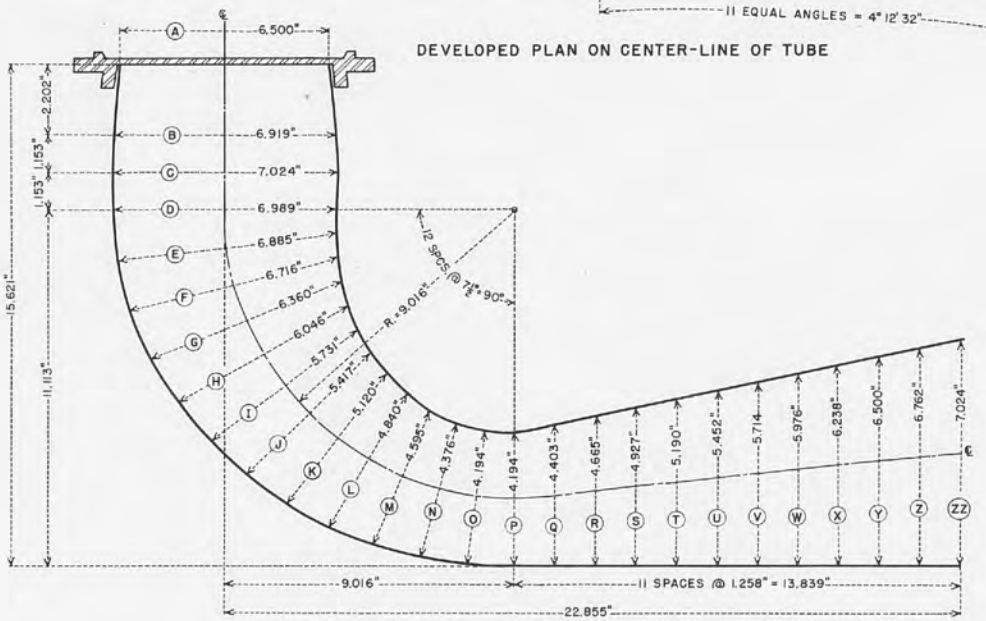
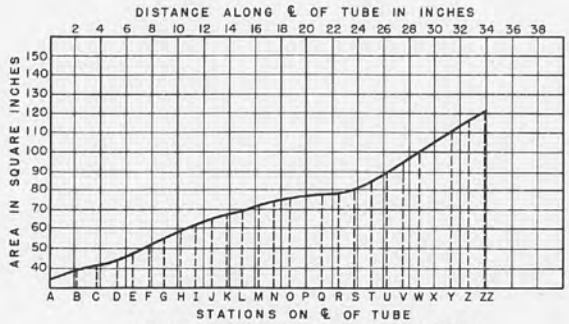


DEVELOPED PLAN ON CENTER-LINE OF TUBE



SECTION ON CENTER-LINE OF TUBE



CURVE SHOWING AREAS OF SECTIONS
ALONG CENTER-LINE OF TUBE

GRAND COULEE DRAFT TUBE MODEL TESTS

GRAND COULEE TUBE

222-D-6100