OPTIONAL FORM NO. 10
5010-104

UNITED STATES GOVERNMENT

Memorandum

Memorandum

TO : H. M. Martin

Denver, Colorado

DATE: November 2, 1964

FROM : D. Colgate

SUBJECT: DESIGN, CONSTRUCTION, AND CALIBRATION OF A ROTATING DISC APPARATUS FOR TESTING PROTECTIVE COATINGS

PURPOSE

The Chemical Engineering Branch had need for a rotating-disc-type test apparatus to aid in the study of the effect of flowing water on various protective coatings. Such an apparatus, in which the velocity and direction of flow were known for all points on the disc, was not available. This report describes the design and calibration of a rotating, multiple-disc test apparatus designed by the Hydraulics Branch.

DESIGN

Requirements

The initial requirements to be met in the design of the rotating disc test apparatus were: (1) the apparatus should contain four discs so that simultaneous testing of different coatings could be performed, (2) the method of coating, installing, and removing of discs should be simple, (3) the peripheral velocity of the discs should be about 30 fps, and (4) the apparatus and fluid tank should be portable.

Disc Diameter and Rotation Speed

The major considerations in determining the disc diameter were the ease-of-handling requirement and the availability of electric motors and gear trains to produce the required 30 fps peripheral velocity of the disc.

A disc 8 or 9 inches in diameter was considered desirable for easy application of protective coatings for testing. For rigidity a disc thickness of 1/4 inch was considered optimum.

A review of commercial electrical equipment indicated that a reduction gear box which produced a counter-shaft speed of 780 rpm when driven by a 1,740-rpm motor was available as a "shelf item." When rotating at 780 rpm, a disc 9 inches in diameter will produce a disc peripheral velocity of 30.6 fps. Therefore, a disc 9 inches in diameter and 1/4 inch thick, and a rotational speed of 780 rpm were chosen for the test apparatus.

Motor Size Determination

One 9-inch-diameter, 1/4-inch-thick disc rotating at 780 rpm in water will require about 0.47 horsepower. To rotate the four discs of the test apparatus will require 1.88 horsepower. This demand, together with bearing and gear train losses and a suitable safety factor, lead to the choice of a 3-horsepower electric motor to rotate the test discs in the apparatus.

The power unit, consisting of a 3-horsepower, 440-volt, high-starting torque electric motor, and a reduction gear train to produce a countershaft speed of 780 rpm, was purchased from a commercial firm. The unit was designed to operate with a vertical axis of rotation and with a lubrication system which would permit horizontal storage without lubricant leakage (see Figure 2).

Disc Chamber Design

Several configurations of disc chambers, including interrupting vanes on the fixed portion of the basin and counter-rotating discs were considered to counteract rotational flow. Each of these designs contained undesirable features. For example, vanes in the chamber would preclude the use of the chamber walls as test surfaces, and the mechanism required to produce counter-rotation in adjacent discs would be quite complicated.

It was decided to allow each disc to rotate in separate, identical chambers. Since each disc would rotate in the center of a chamber, eight identical test areas were available.

With the above consideration in mind, the details of the four-disc apparatus were completed (Figure 1). All parts of the discs, chambers, and connecting framework were fabricated and assembled in the Research Division shops. The space in which each disc rotates is 3/4 inch thick.

Figure 2A shows the motor, reduction gear box, and the partially assembled rotating discs and stationary chambers. The fully assembled test apparatus is shown in Figure 2B. The four rotating discs with their spacers are held on the rotating shaft with one nut. The stationary chambers are held in place with three bolts. Assembly and disassembly are easily accomplished. The apparatus as a unit, including the reservoir, is portable.

For ease in assembly and operation, the apparatus was mounted on two trunnions over a water reservoir. When conducting a test, the test head was rotated into the reservoir, and the apparatus locked in place with locking clamps on each trunnion (Figures 2-C and D).

To permit the free movement of water through the system, a 2-1/4-inch-diameter hole was bored in the center of each stationary plate, six 1/2-inch-diameter holes drilled in each rotating disc, and six 3/8-inch-diameter holes drilled in the outer edge of each disc chamber. (See Figure 1.) When operating submerged, the system was almost vibration-free. The water circulated freely through the four disc chambers and the reservoir (Figure 2D). During a 3-hour test run, the motor and bearings were cool and the reservoir water remained at room temperature.

CALIBRATION

Four pitot tube stations were installed in the upper stationary chamber to measure the flow direction and determine the flow velocity in the 1/4-inch space between the rotating disc and the chamber wall (Figure 1). A single leg impact tube (Figure 3) was used to determine the total head at each of four stations located 1.64, 2.57, 3.55, and 4.50 inches from the center of the disc. The tube was then removed and the pressure head measured at the point where the tube had been inserted into the chamber. Since the total head measuring station and the pressure head station were at different locations, a plot of each measurement with respect to its location on a radius was made. The velocity head, or the difference between the total head and pressure head, was then plotted for all points on a radius (Figure 3).

The computed flow velocity with respect to the fixed chamber wall (or fixed plate) and the angle of the direction of flow from a radial line, were plotted for various distances from the center of rotation (Figure 4). Also, the velocity of the rotating disc along a radial line was computed and plotted on the same chart.

The flow velocity and direction with respect to the rotating disc was determined graphically (Figure 5). For various points on any radius, a graphical representation of the computed disc surface velocity was drawn.

From the origin a line to represent the measured direction and velocity of the flow with respect to the fixed plate was drawn. The closing line then represented the direction and velocity of the flow with respect to the surface of the rotating disc. The values thus determined were plotted on Figure 4.

The results of the foregoing computations were plotted for both the fixed plate and the rotating disc. The plots represent, with respect to the walls of the fixed chamber, (Figure 6) or the rotating disc (Figure 7) the path of a particle of water as it enters the chamber near the center and leaves at the outer edge. The velocity and direction of flow for any point in either the fixed plate or the rotating disc can be determined from these two charts.

SUMMARY

1. The rotating disc apparatus as designed will operate quite smoothly and can run unattended for long periods without damage to the system.

2. Uniform surface texture of the test coat on a rotating disc face and the adjacent stationary chamber wall is necessary to assure that the relative path-and-velocity charts (Figures 6 and 7) are valid. Each of the eight separate test areas may, however, contain test coatings with different surface textures.

3. When the 9-inch-diameter discs are rotating at 780 rpm, a maximum relative velocity of 17.2 fps will exist between the water and each rotating disc, and 13.7 fps between the water and the stationary walls of the chambers in which the discs rotate. (Figures 6 and 7.)

4. The apparatus is portable and operates smoothly under continuous service. The test surfaces can be quickly assembled and disassembled for inspection or application of test coatings.

D. Colgate

OPERATION

An information bulletin from a private protective coatings firm indicated that a rotating disc as described herein would be a valuable test facility. The bulletin prompted construction of the laboratory rotating disc test apparatus.

The apparatus as delivered to the Protective Coatings Branch operated as described in the memorandum. However, a test run of about 200 hours duration with a red lead coating failed to produce any discernible damage. The Protective Coatings Branch changed the motor gear ratio such that the discs would rotate at 1,560 rpm producing a relative velocity of about 35 feet per second between the water and the discs. The test was repeated with a run of about 300 hours duration and still no discernible damage was noted on the red lead coating of the discs.

Since the apparatus apparently does not produce the anticipated results, this memorandum is not intended for general publication.

(Note: In Chemical Engineering Branch Report No. ChE-25 "Resistance to Cavitation Damage Laboratory and Field Tests on Four Selected Coatings," photographs of the outlet conduits at Grand Coulee Dam appear in which red lead had been applied to surfaces adjacent to a test coating boundary. Although the red lead was not intended to be included in the test program, the surfaces were nonetheless in the area of high velocity flow. The red lead coatings were subjected to 103, 159, 508, and 1,012 hours of exposure under a velocity of 96 feet per second without apparent distress. It appears that the rotating disc apparatus as constructed or as modified will be inadequate as a test facility for coatings as durable as red lead.)

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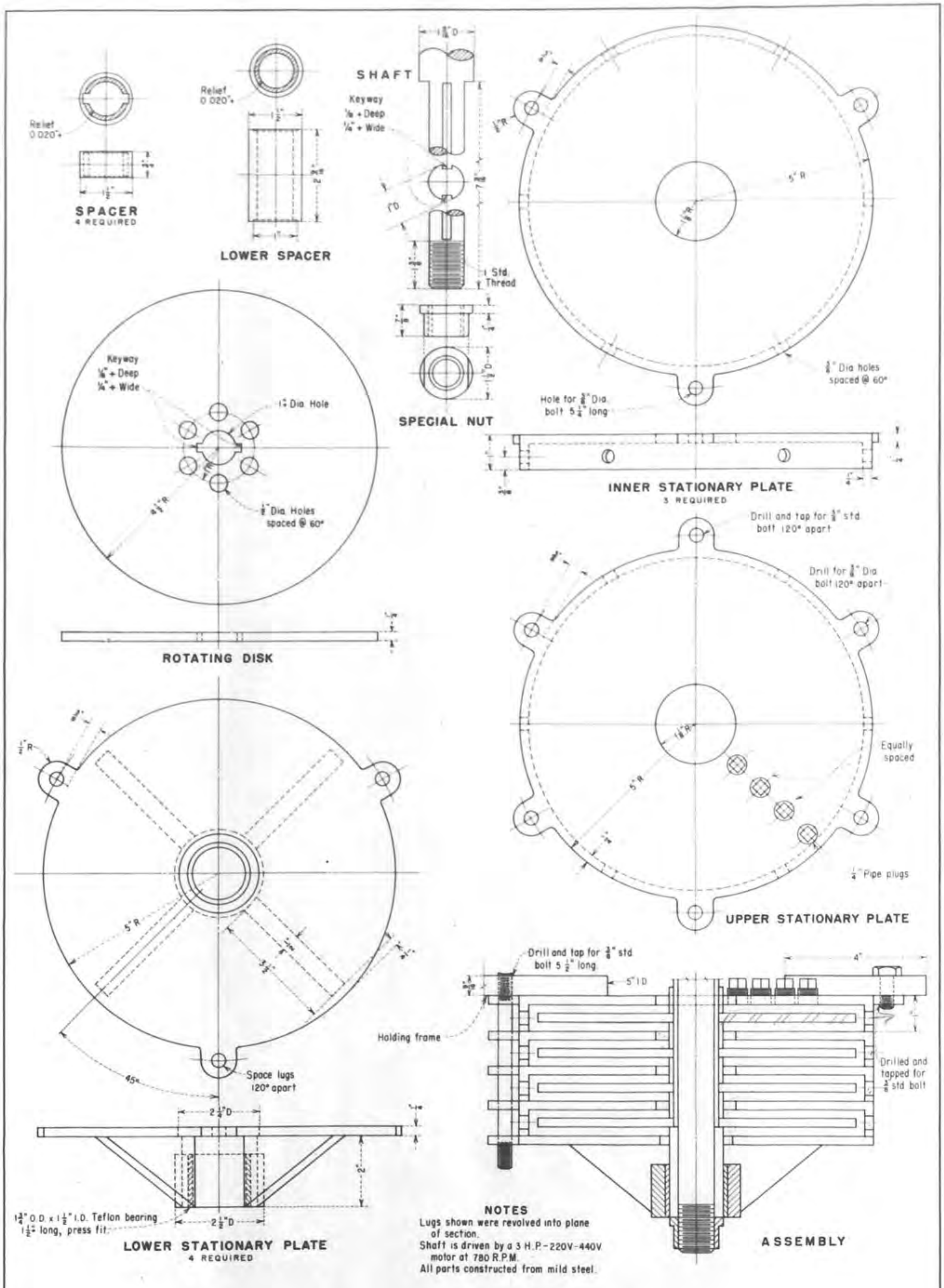
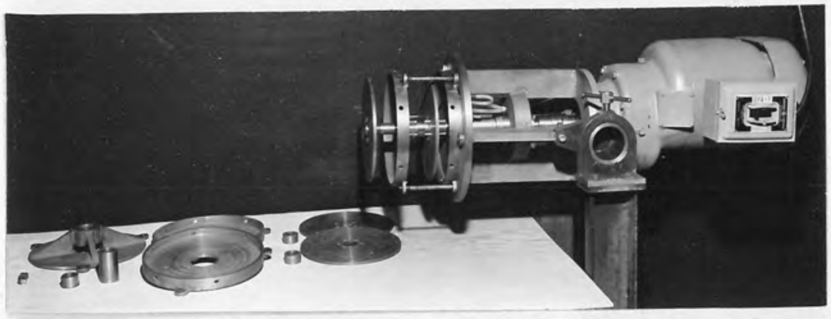
ABSTRACT

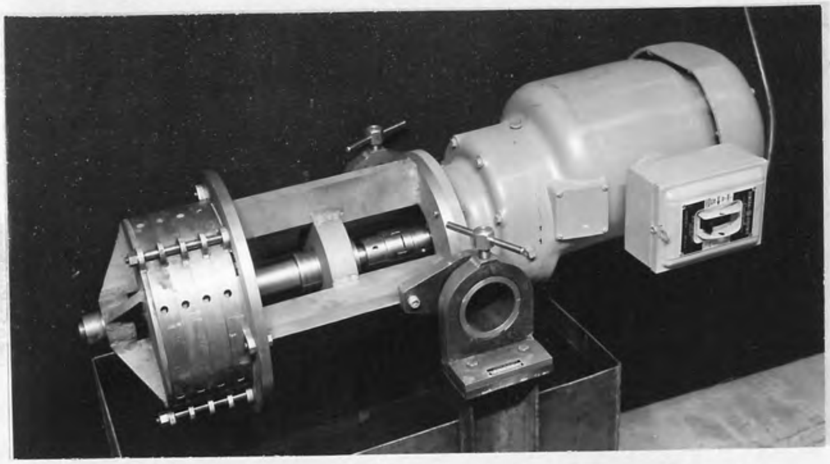
A rotating disc test apparatus was fabricated and calibrated for use in studying the durability of protective coatings when subjected to flowing water. The apparatus contains four 9-inch-diameter discs fixed to a common shaft rotating at 780 rpm. At this rotational speed, the maximum relative velocities were determined to be 17.2 fps between the water and the rotating disc and 13.7 fps between the water and the stationary walls of the chambers. The apparatus is portable and operates smoothly under continuous service. The test surfaces can be quickly assembled and disassembled for inspection and application of test coatings. Uniform surface texture of the test coat on a rotating disc face and the adjacent stationary chamber wall is necessary to assure valid test results. The report discusses the design of the apparatus, the method used in calibrating it, and its limitations in testing protective coatings.



ROTATING DISK TEST APPARATUS
DETAILS OF DISK AND CHAMBER



A. Apparatus ready for assembly.



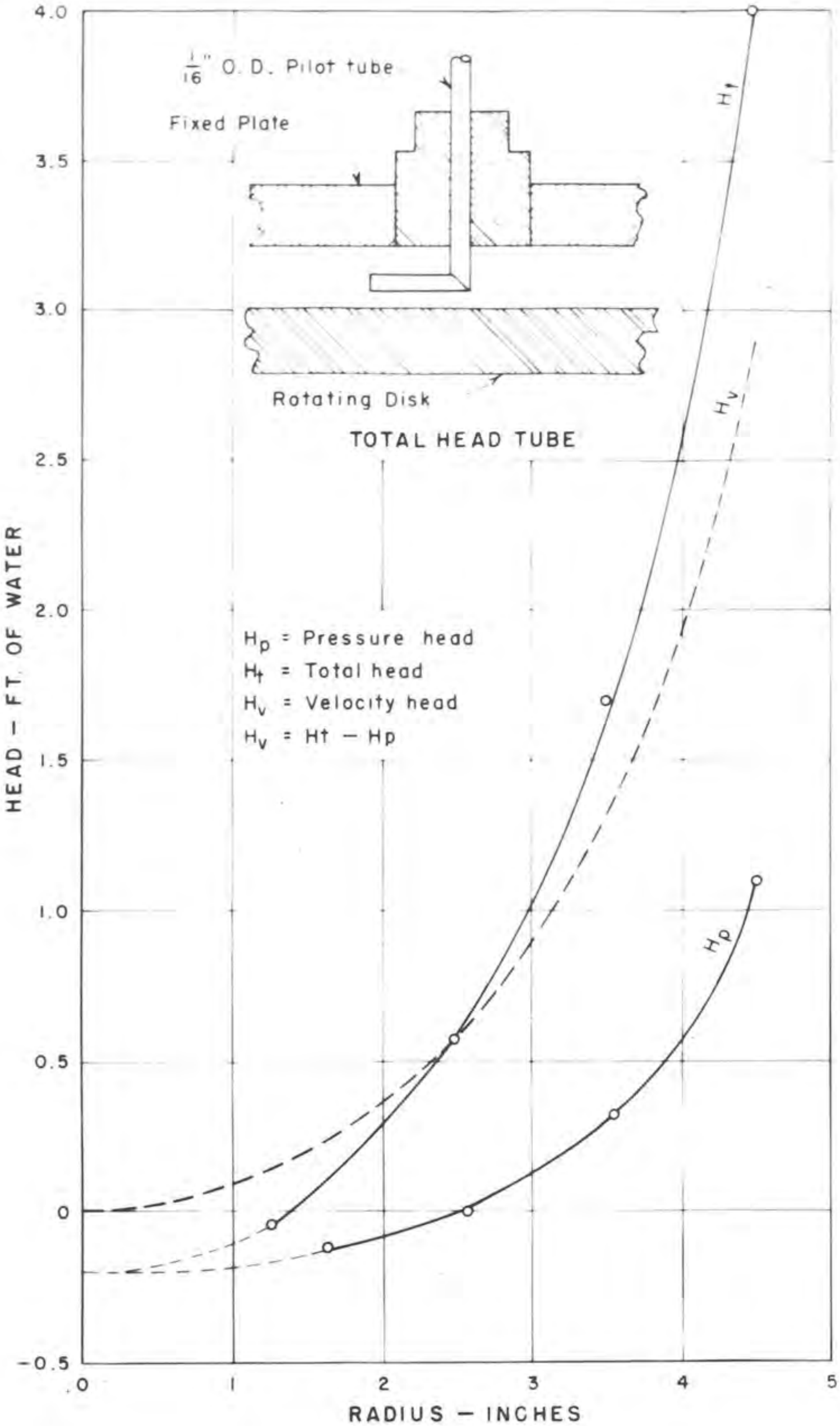
B. Apparatus assembled, clamped horizontally.

C. Rotating the apparatus into the reservoir.

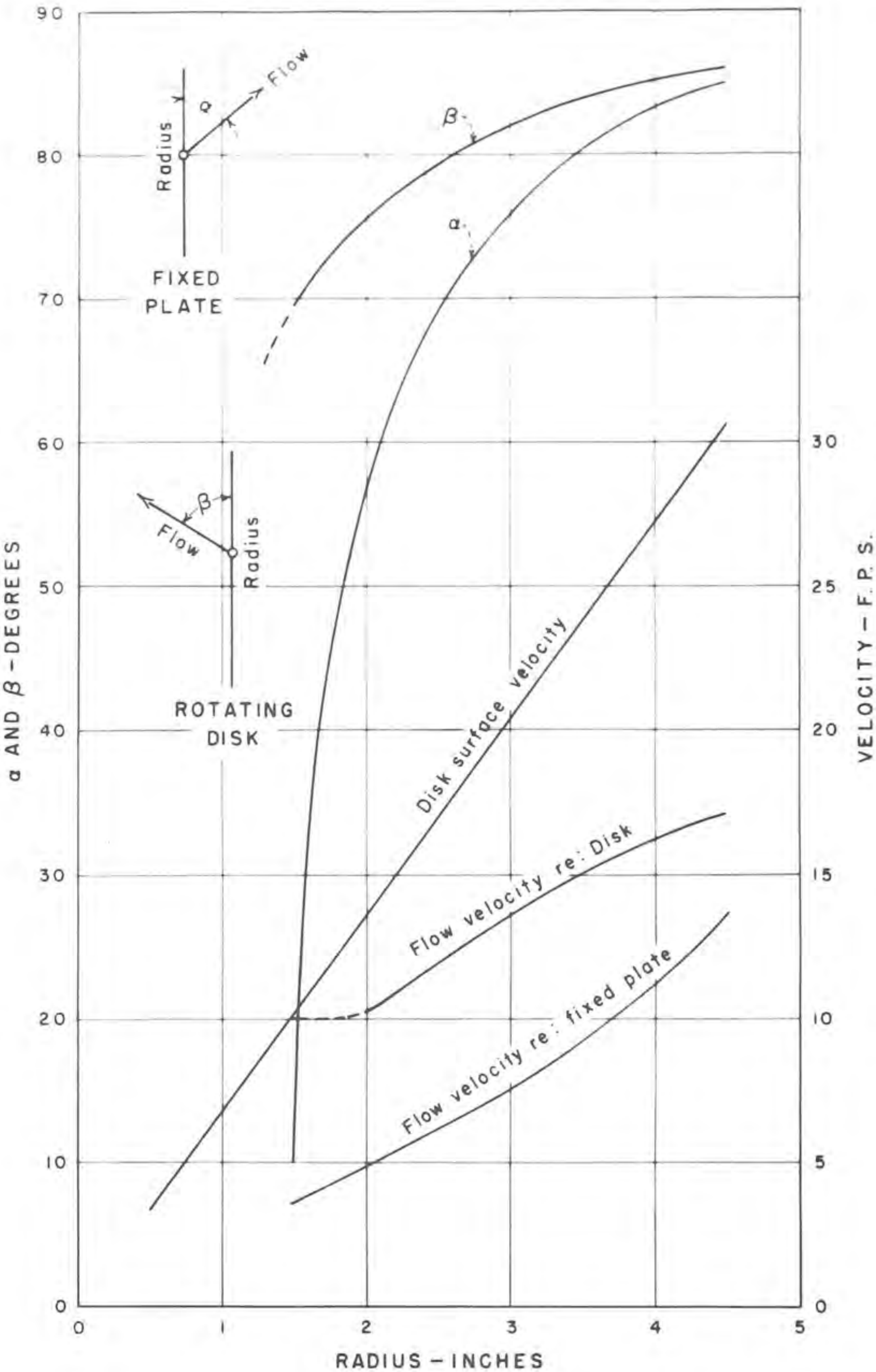
D. Apparatus operating at 780 rpm. Note slight turbulence on the water surface.

ROTATING DISC TEST APPARATUS

Assembly and Operating Views

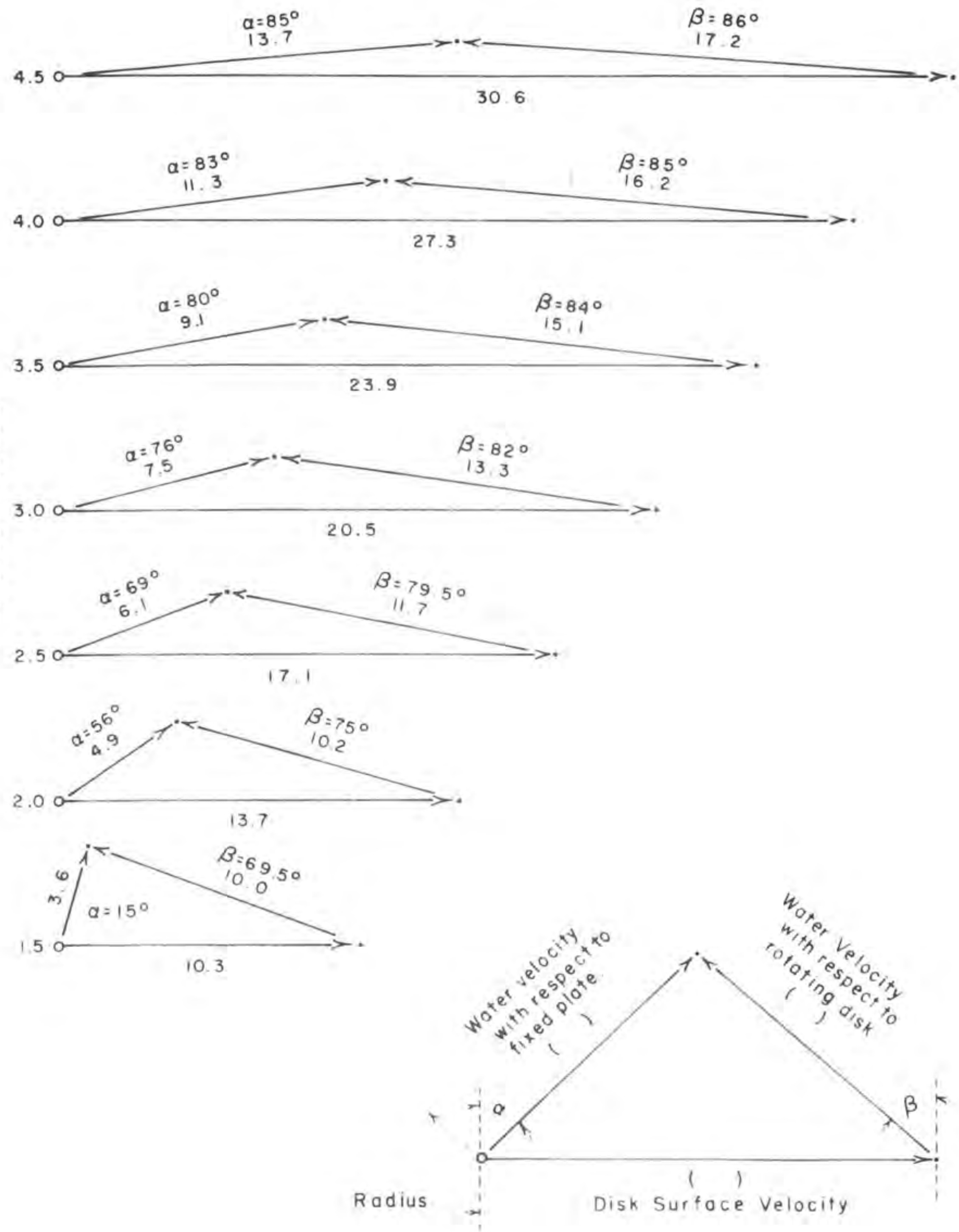


ROTATING DISK TEST APPARATUS
PRELIMINARY HEAD MEASUREMENTS

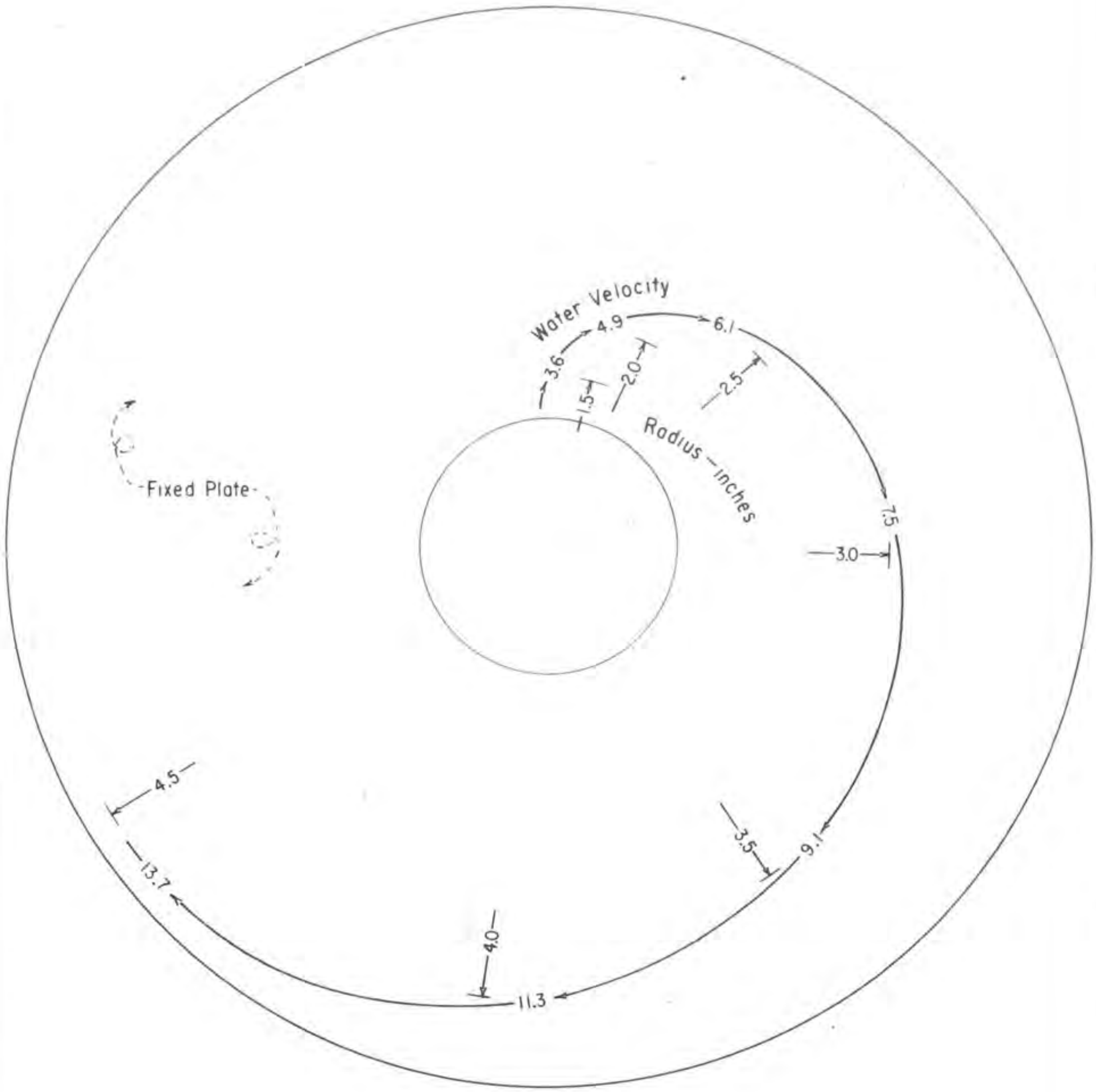


ROTATING DISK TEST APPARATUS
VELOCITIES AND DIRECTIONS OF FLOW

680

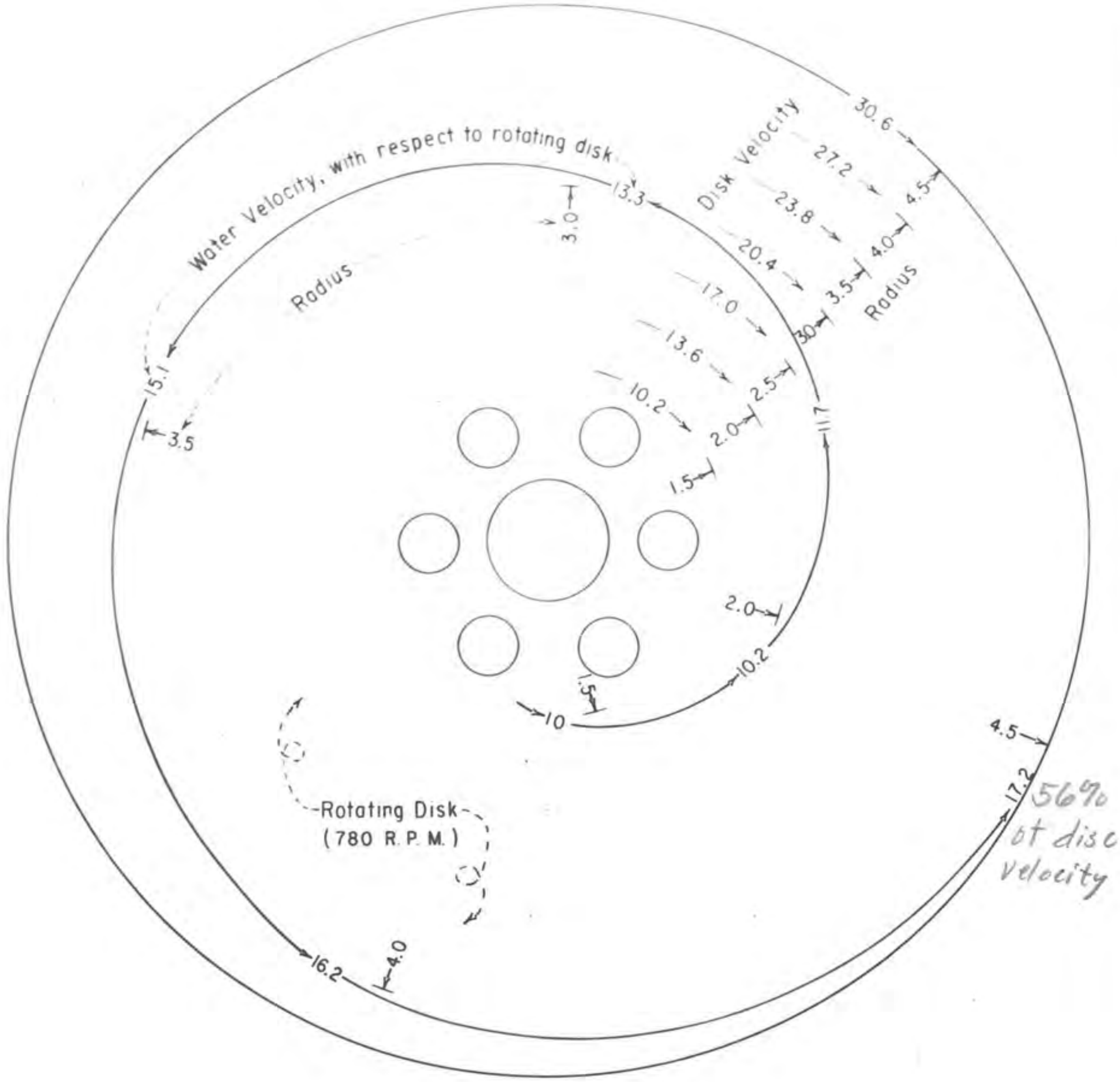


ROTATING DISK TEST APPARATUS
GRAPHICAL SOLUTION OF VELOCITIES
AND DIRECTIONS OF FLOW



ROTATING DISK TEST APPARATUS
PATH AND VELOCITY OF FLOW WITH RESPECT TO FIXED PLATE

680



ROTATING DISK TEST APPARATUS

PATH AND VELOCITY OF FLOW WITH RESPECT TO DISK

680