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UNITED STATES GOVER[NMENT]

Memorand[um]

Memorandum

Denver, Colorado

TO : H. M. Martin

DATE: April 14, 1961

FROM : W. P. Simmons, Jr.

SUBJECT: Cylindrical Pitot tube and supporting mount for studies in a high head, high velocity closed conduit flow system

A special velocity-measuring instrument and supporting mount have been designed and constructed in the Division of Engineering Laboratories in Denver to meet the difficult requirements of a high-head test facility. This facility is used to study the inception of cavitation and the effects of this cavitation in regions downstream from an orifice in a pipeline flowing full of water. Heads up to 500 feet of water and velocities up to 100 miles per hour are used in the laboratory study.

Measurements of the velocity patterns at several stations in the pipeline near and farther downstream from the orifice plates are required in the study. Pitot static tubes of the usual L-shaped design with the tip extending upstream are often used for these measurements when flow velocities are moderate or low. This type tube was not suitable for the present tests because the upstream projection was unstable in high velocity flows, and the cantilevered mounting was too weak for adequate support. A cylindrical tube which extended clear across the pipe, to be supported at each wall, and which does not have a projecting leg, was much more satisfactory. This type of tube, using a hole pointed directly upstream to measure total head, and two holes drilled 39-1/4° around the cylinder on each side of the center hole to measure static pressure, was used in the tests. Each of the holes was connected to a separate small tube which transmitted the pressure from that hole to a terminal at the outboard end of the instrument. From these terminals, connections were made to pressure indicating gages. Directional sensitivity was obtained by rotating the tube until the two static pressure openings indicated the same pressure and were thereby oriented so the center hole faced directly into the flow. Flow direction was shown by a pointer clamped to the tube directly in line with the center hole.

A small-diameter instrument was needed because the tests were conducted in a 3-1/16-inch-inside-diameter pipe with orifice plates ranging downward in size to 1 inch. A diameter of 1/8 inch was selected, and the instrument was made of stainless steel to obtain maximum rigidity combined with high corrosion resistance. The three pressure leads from the two static pressure holes and the total pressure hole were made of stainless steel hypodermic needle tubing 0.032 inch in diameter. All these tubes were contained within the interior of the 1/8-inch-outside-diameter main tubing. All components were carefully machined, alined, and finally assembled using silver solder. The careful and precise work done by the machinist on these very small components produced the accurate and strong measuring instrument needed for the studies.

The response of the tube was determined by calibrating it in a 3-inch-diameter pipeline with a known rate of flow occurring through it. Sufficient length (25 D) of straight conduit preceded the calibration station to insure a uniform and fully developed velocity distribution. Measurements were made of the static and total heads indicated by the tube in traverses across the pipe, and the static heads indicated by two diametrically opposed and accurately machined wall taps. The static head indicated by the tube was lower than that measured by the wall taps, probably due to a slight misplacement of the holes around the cylinder of the tube. By adding a correction factor of 9.3 percent of the indicated velocity head to the indicated static head, the true static head is obtained. Subtraction of the corrected static head from the total head produces the correct velocity head. Plots of velocity profiles obtained in this manner showed excellent agreement with the expected profiles, and the calibration was considered complete.

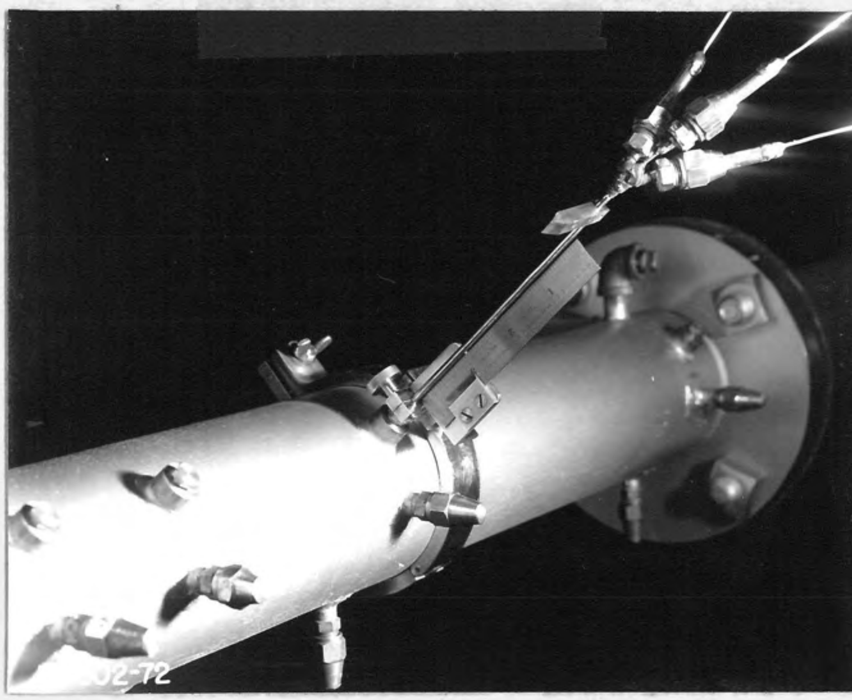
To use the tube to full advantage, a mount was needed for positioning and supporting it. Measurements were planned at several stations along the pipeline, and a mount that could be rapidly shifted from place to place was desirable. A hinged, clamp-type mount that circled the pipe was therefore selected. Three areas of contact were provided on the inside diameter of the mount so it would fit tightly in place in spite of any minor out-of-roundness of the pipe. A split block drilled to receive the 1/8-inch-diameter tube, and fitted with a clamping screw, was carried above and to one side of the clamping ring. When the split block was loosened, the tube could be moved up or down or rotated. When the block was tightened, the tube was gripped firmly. The position of the measuring holes of the instrument along the traverse line across the pipe was set by alining a scribed mark on the tube with the markings on a 4-inch precision rule clamped above the holding block. This rule, or scale, could be moved up or down sufficiently to place the markings precisely on the tube scribe mark after the tube had been properly indexed on the traverse line. After adjustment, the reference rule was clamped firmly in place.

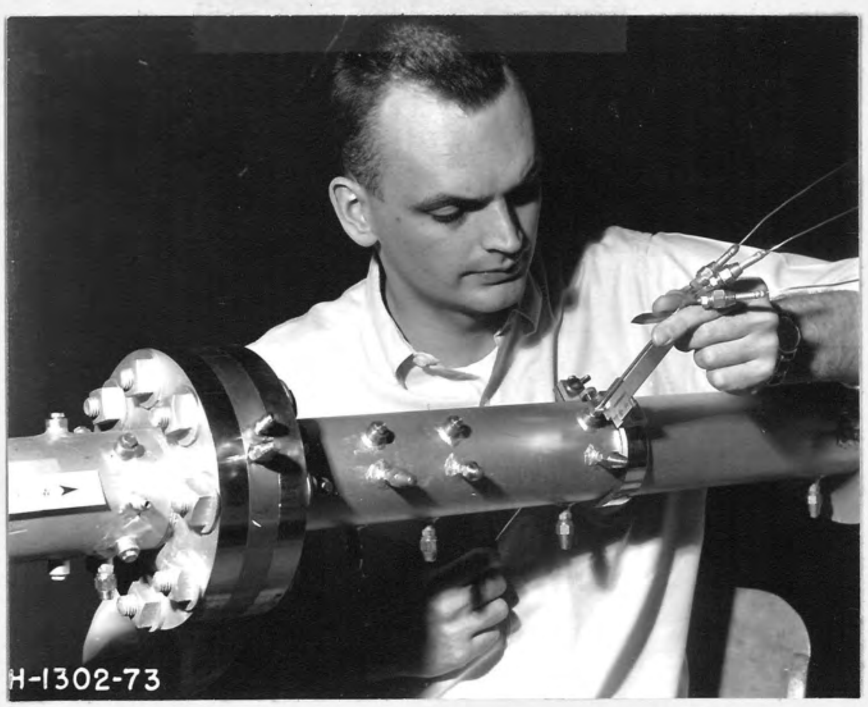
The Pitot tube entered the pipeline through small packing glands. A gland consisted of a boss that was soft-soldered to the pipeline, a 1/8 by 1/4 by 1/16 circular ring packing, and a packing nut. These glands worked excellently, and the tube could be moved relatively freely through them. Only finger pressure was needed to tighten the nuts sufficiently to make the glands drop tight against a 500-foot head.

The high heads used in the tests required that all gages, U-tubes, and pressure lines be capable of withstanding high pressures. This posed a special problem for the leads conducting pressures from the 1/8-inch tube to the gages. One-quarter-inch-diameter seran tubes withstood the pressures satisfactorily, but three of these large and stiff tubes produced a severe bending load on the tiny Pitot tube. Wire-reinforced tygon tubing was more flexible, but sealing problems at the connections were serious. A better solution was found in the use of 1/16-inch-outside-diameter by 1/32-inch-inside-diameter brass tubing annealed to the full soft state. These leads were 3 feet long and were arched or looped so that they placed very little strain on the Pitot tube. The metal leads withstood the high internal pressures through repeated bending cycles and were used with complete satisfaction for the majority of the tests.

By use of this cylindrical Pitot tube and its supporting mount, velocity distribution studies downstream from high-head orifices became feasible. At the present time, a comprehensive study downstream from a 1-5/8-inch orifice is well advanced. In the future, it is expected that studies will be continued using a 2-5/8-inch and a 1-inch orifice. At the completion of the studies, the data will be prepared in report form, and possibly in the form of a technical paper, for dissemination to the engineering profession.

The versatility and usefulness of cylindrical Pitot tubes have not gone unnoticed in the past, and tubes of this type have been used in previous laboratory studies. The first use was in model studies determining velocity profiles in flows approaching the pump inlets for Grand Coulee Pumping Plant, Columbia Basin Project. This work is described in Report Hyd-64, dated August 21, 1939. The same tube was used for studies made in 1953 of turbine bypass stilling basins for Pole Hill and Flatiron Powerplants, Colorado-Big Thompson Project. These studies are discussed in Report Hyd-353. Much larger versions of the tube were used in determining velocity profiles and flow directions in draft tubes of two turbine bypass energy absorbers tested on a 1:4.5 scale at Estes Powerplant. These studies are presented in Report Hyd-348, published March 12, 1956. On a limited scale, other occasional uses have been made of these tubes.

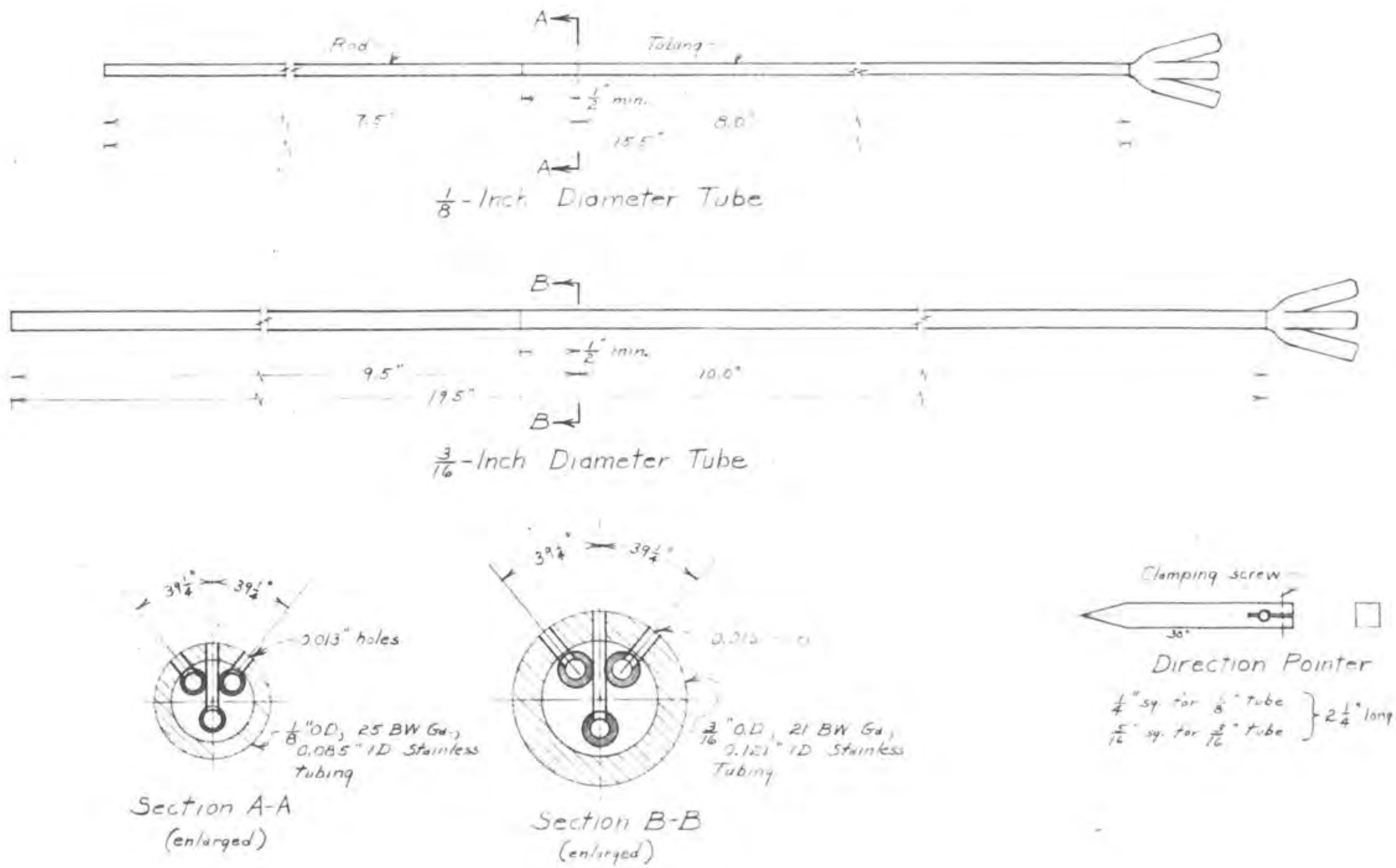




1/8 - INCH DIAMETER HIGH VELOCITY PITOT TUBE
AND MOUNT

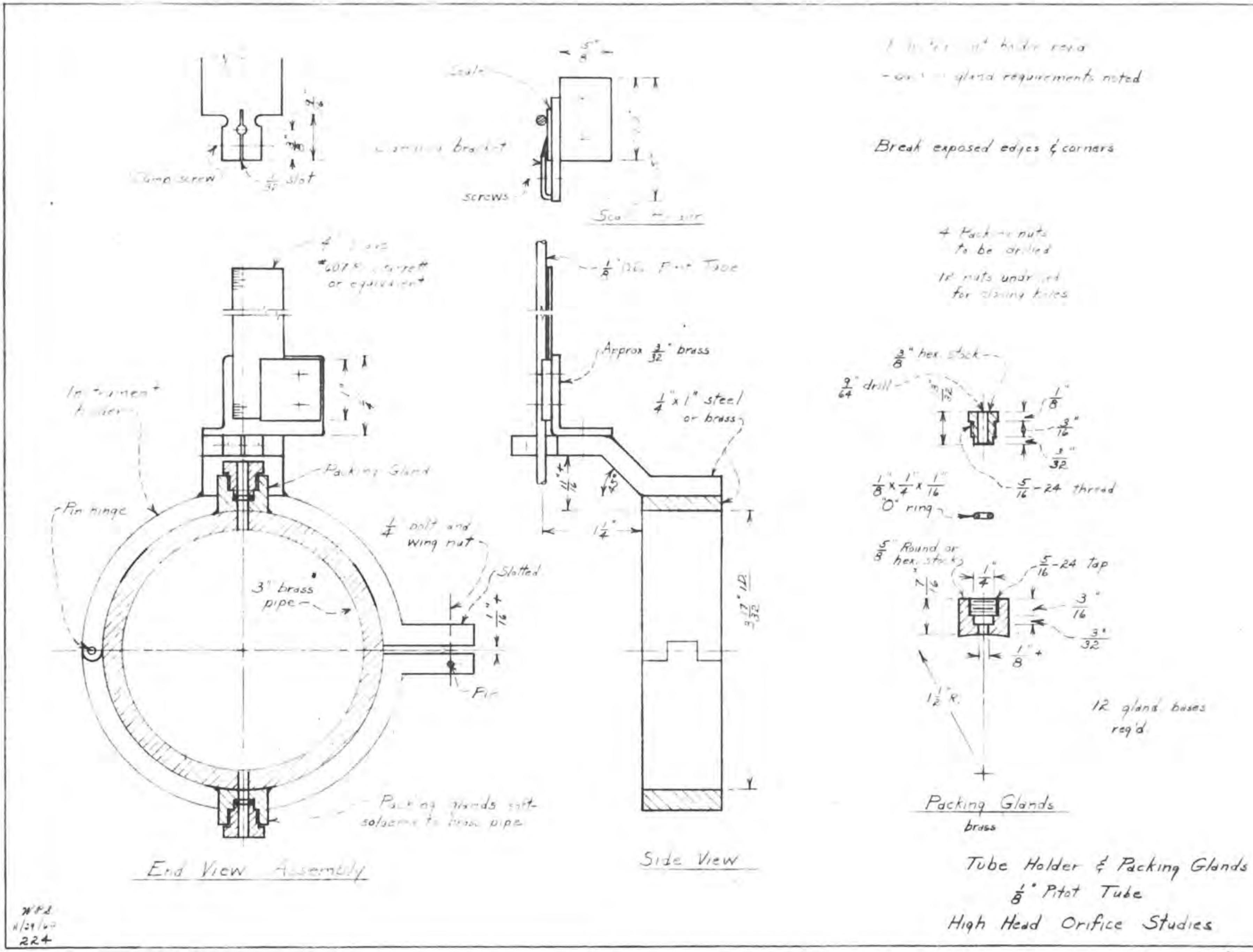
CYLINDRICAL PITOT-STATIC TUBES — 3 HOLE

$\frac{1}{8}$ and $\frac{3}{16}$-Inch Diameters



Materials List — *21 Gage (0.032") stainless hypodermic needle tubing (0.020" I.D.) Type 304S – 36"
*20 Gage (0.035") stainless hypodermic needle tubing (0.023" I.D.) " " – 36"
$\frac{1}{8}$-inch OD, 25 Gage, 0.085 inch ID stainless steel tubing " " – 10"
$\frac{3}{16}$-inch OD, 21 Gage, 0.121 inch ID stainless steel tubing 314W – 12"
$\frac{1}{8}$-inch OD rod, stainless steel – 9"
$\frac{1}{16}$-inch OD rod, stainless steel – 11"
$\frac{1}{8}$-inch & $\frac{5}{16}$-inch brass, square bar.

11/4/60
W.P.S.



Break exposed edges & corners
Scale
screws
1/32 slot
1/8" O.D. Pitot Tube
Approx 3/32" brass
1/4" x 1" steel or brass
Packing Gland
Pin hinge
1/4 bolt and wing nut
Slotted
3" brass pipe
Pin
End View Assembly
Side View
4 Packing nuts to be drilled
3/8" hex stock
9/64" drill
5/16-24 thread
1/8 x 1/4 x 1/16 "O" ring
5/8" Round or hex stock
5/16-24 tap
1 1/2" R
12 gland bases req'd
Packing Glands
brass
Tube Holder & Packing Glands
1/8" Pitot Tube
High Head Orifice Studies
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