An investigation of a pipe bend for determining the amount of flow of water in a small pipe

by John M Batch

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering at Montana State College
Montana State University

Abstract:
The purpose of this investigation was to study the possibility using a pipe bend to measure the quantity of flow of water in a small pipe, The flow was to be metered by measuring the pressure difference across the inside and put-side curves of the pipe bend. Advantages of a pipe bend flow meter include low in itial cost and no additional resistance to flow Tests were run on 90 degree solder-joint oast bronze elbows of sizes from 3/8 inch to 1 inch, and pipe, bends of 3/8 inch outside diameter copper tubing with constant radii but varying amounts of bend. It was found from the tests that when the pressure difference across the curves of the pipe bend and flow were plotted on logarithmic graph paper the curve was a straight line Also it was found that there was a linear relation between pressure difference and the square of the mean velocity of flow, It was concluded from the tests that a small pipe bend may be made into a flow meter with satisfactory results. Pipe bends from 7 1/2 to 180 degrees of bend were tested and found accurate When used as a flow meter. It was also concluded that the pipe bends should be calibrated in the laboratory before being used in an actual installation.

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ABSTRACT OF THE THESIS

The purpose of this investigation was to study the possibility of using a pipe bend to measure the quantity of flow of water in a small pipe. The flow was to be metered by measuring the pressure difference across the inside and outside curves of the pipe bend.

Advantages of a pipe bend flow meter include low initial cost and no additional resistance to flow.

Tests were run on 90 degree solder-joint cast bronze elbows of sizes from 3/8 inch to 1 inch, and pipe bends of 3/8 inch outside diameter copper tubing with constant radii but varying amounts of bend.

It was found from the tests that when the pressure difference across the curves of the pipe bend and flow were plotted on logarithmic graph paper the curve was a straight line. Also it was found that there was a linear relation between pressure difference and the square of the mean velocity of flow.

It was concluded from the tests that a small pipe bend may be made into a flow meter with satisfactory results. Pipe bends from 7 1/2 to 180 degrees of bend were tested and found accurate when used as a flow meter. It was also concluded that the pipe bends should be calibrated in the laboratory before being used in an actual installation.

CHAPTER I

THE PROBLEM

Statement of the problem. It was the purpose of this study to investigate the possibility of using a pipe bend to measure the quantity of flow of water in small copper pipes. This was to be accomplished by measuring the pressure difference of the water between the inside and outside curves of the bend as shown in Figure 1.

Validation of the problem. When water is flowing in a closed pipe system, operating under a small pressure head, it is often necessary to measure the quantity of water flowing. This necessitates a flow meter that will add a negligible pressure drop to the existing system. It is a characteristic of a flow meter constructed from an existing pipe bend that there is no additional resistance to flow.

The relative simplicity and the small original cost are also desirable qualities of a flow meter constructed from a pipe bend.

Organization of the thesis. The material presented in this study includes (1) the results of tests made on commercial cast bronze 90 degree elbows of sizes between 3/8 inch and 1 inch; (2) the results of tests made on pipe bends of constant radius and diameter but of varying amount of bend;

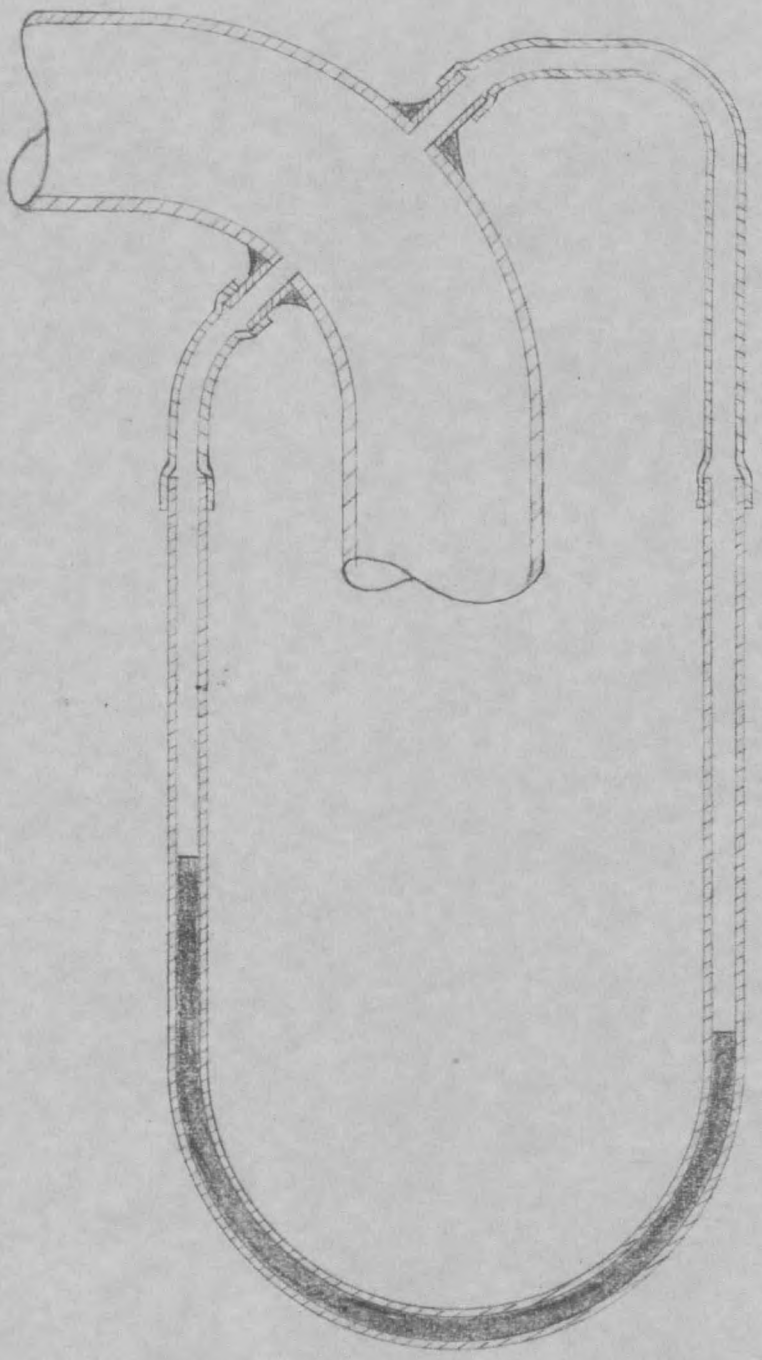

FIGURE 1

CROSS SECTION OF PIPE BEND SHOWING METHOD OF MEASURING PRESSURE DIFFERENCE

and (3) an effort to predict the results by mathematical analysis.

Review of the literature. There has not been a great deal of literature published on the subject of using a pipe bend as a flow meter. The subject, however, is not a new one. In 1914 Levin[1] described in an article a flow meter that had the general shape of a pipe elbow, but with a square cross section. Test data gathered from experiments on steam as a flowing fluid was presented.

In an article published in Power[2] a flow meter of a rectangular hyperbolic section was shown. The meter was preceded by straightening vanes and had a rather complicated recording apparatus.

Yarnell and Nagler,[3] in a study of the characteristics of flow of water around large plastic pipe bends, mention that a pipe bend could be used to meter the flow. However, their main study was confined to the flow lines through the bend and the drop in static pressure due to the bend. In their discussion of static pressures they bring out the idea of the pipe bend being used as a flow meter.

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[1] A. M. Levin, "A Flow Metering Apparatus," Transactions A.S.M.E., 36:239-54, September 1914.

[2] "The Hyperbo Electric Flow Meter," Power, 57:1024-25, June 26, 1923.

[3] David L. Yarnell and Floyd A. Nagler, "Flow of Water Around Bends in Pipes," Transactions A.S.C.E., 100:1018-32, 1935

Ireal A. Winter[4] did experimental work on the measuring of flow in hydraulic turbines. This was done by tapping the scroll case on the inside and outside bend surfaces and measuring the pressure difference. Fairly good results were obtained by this method although it was concluded that the scroll case should be calibrated against a known flow when converted to a flow meter.

W. M. Lansford[5] has done considerable work on 90 degree elbows used as flow meters. He tested threaded elbows between one inch and four inches in size, and flanged elbows ranging in size from four inches to twenty-four inches. Both the threaded and the flanged type elbows were found satisfactory for use as a flow meter.

Thus while the idea of a pipe bend used as a flow meter is not new the investigations previously undertaken were largely limited to large size elbows, 90 degree elbows, or specially made elbows of odd shapes.

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[4] Ireal A. Winter, "Improved Type of Flow Meter for Hydraulic Turbines," Transactions A.S.C.E., 99:847-66, 1934

[5] W. M. Lansford, "The Use of an Elbow in a Pipe Line For Determing the Rate of Flow in the Pipe," University of Illinois Engineering Experiment Station Bulletin No. 289, December 22, 1936, 36 pp.

CHAPTER II

THE METHOD OF PROCEDURE

In the construction of the flow meters from pipe bends, and in the experimental data collecting, all materials and tools used were of the common type found in any machine shop. No special apparatus was used or constructed so that duplication of the results of this investigation could be possible.

I. CONSTRUCTION OF THE PIPE BENDS

Cast elbows. Nine 90 degree cast bronze solder-joint type elbows were converted to flow meters. The different sizes and construction details are shown in Figure 2. In the construction process tube adapters were silver soldered on the inside and outside bends of the elbow. Holes were then drilled through the surface of the elbow with the tube adapters serving as guides. Care was taken to remove all burrs formed in the drilling operation. All of the cast elbows had a very rough, unmachined surface on the inside and no effort was made to improve this situation.

Long-radius pipe bends. Eleven long-radius pipe bends were made from 3/8 inch outside diameter copper tubing. These bends had a constant radius of bend of 15/16 of an inch but varied in amount of bend from 7 1/2 degrees to 180 degrees.

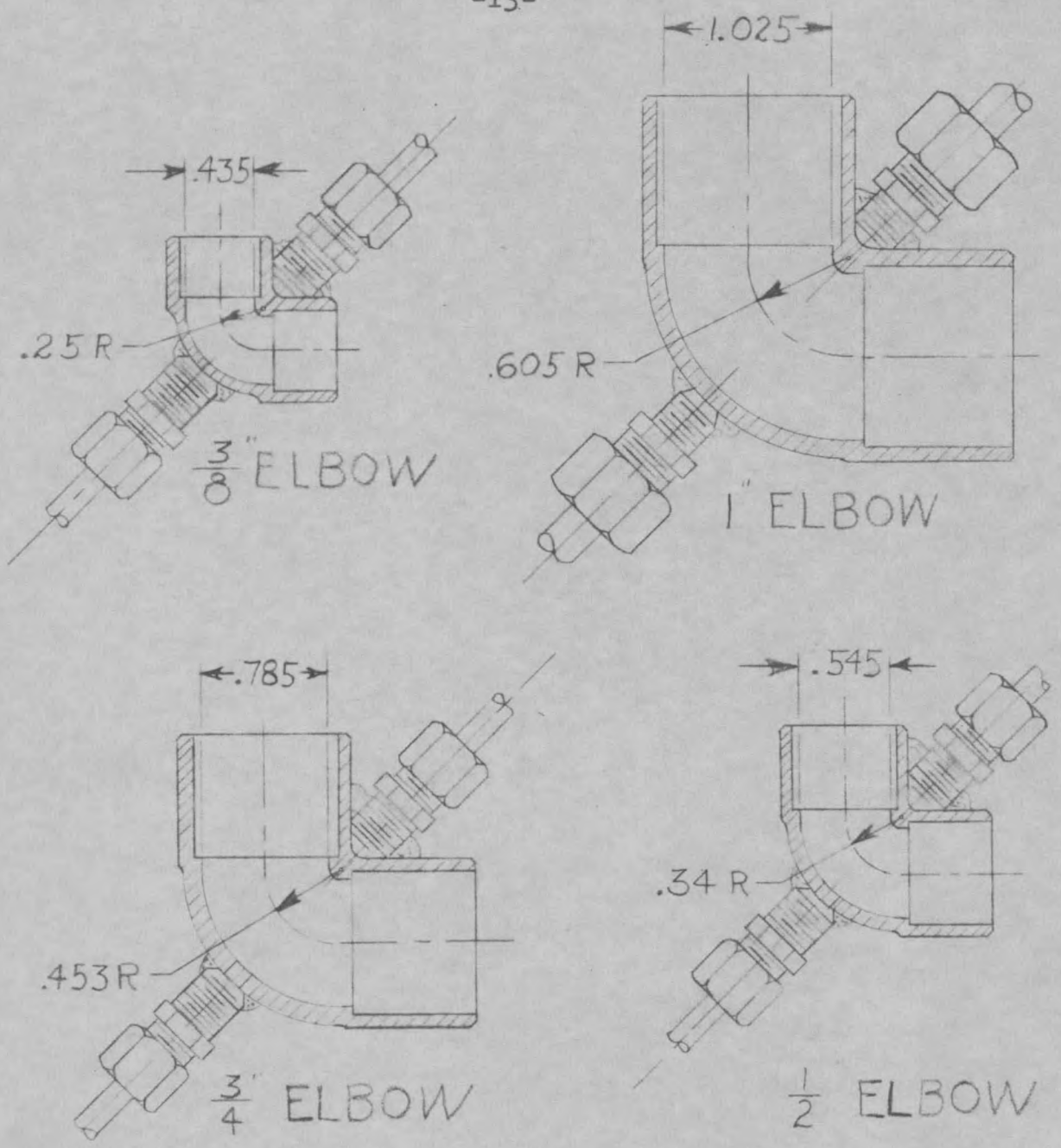

FIGURE 2

CONSTRUCTION DETAILS OF CAST ELBOWS

Seven pipe bends of different amounts of bend were constructed; 7½, 15, 22½, 45, 90, 135, and 180 degrees. Typical construction detail is shown on two of the bends in Figure 3. As these pipe bends were not intended for permanent construction, adapters for copper pipe were not silver soldered on as in the case of the cast elbows. Instead, rubber tubing adapters, in the form of one quarter inch copper tubing, were soldered on the inside and outside of the bend. Holes were drilled through the surfaces of the pipe using the adapters as guides. Very prominent burrs were formed on the inside of the pipe resulting from the drilling operation. These burrs were not removed until after the first series of tests were run in an effort to find the effect of the burrs on the performance of the pipe bend as a flow meter.

II. MEASURING DEVICES USED

Manometers. Straight U-tube manometers were found very satisfactory for measuring the pressure differential across the pipe bends and elbows. Mercury, water, and Gage Fluid No. 3 of the Meriam Instrument Company of Cleveland, Ohio were all used in the manometers. The gage fluid had a specific gravity of 2.95. Water was used in the manometers when the pressure differential was very low, while the gage fluid and mercury were used for pressure differences of higher values.

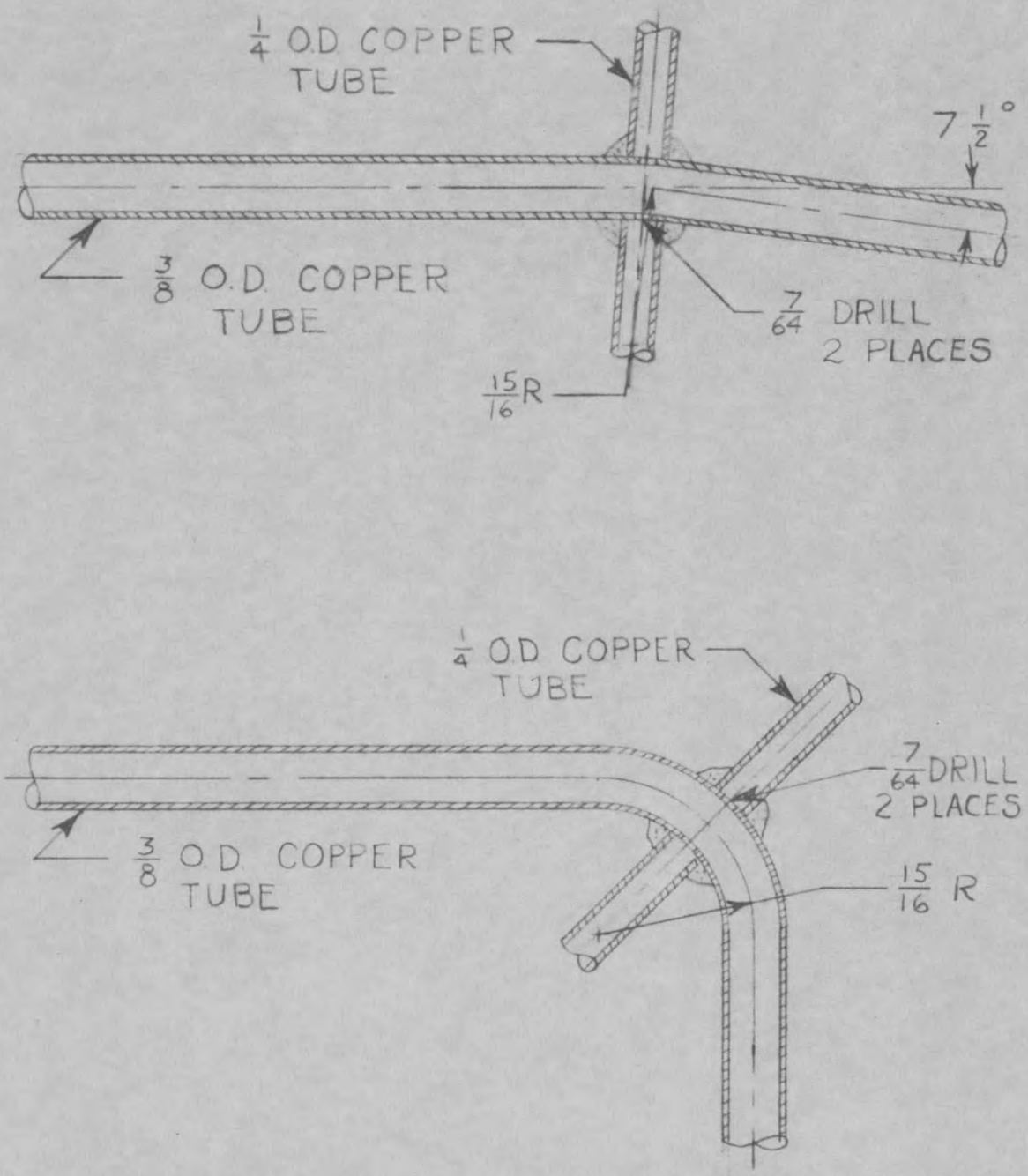

FIGURE 3

CONSTRUCTION DETAILS OF LONG RADIUS PIPE BENDS

A metric recording meter. A recording pressure differential meter was obtained from the American Meter Company of Philiadelphia and was used to record some of the readings on the cast elbows. The meter had a float resting in mercury which was acted on by the differential pressure below and above the float. The float in turn actuated a marking point which recorded the reading on a rotating chart. The meter recorded a maximum pressure differential of either two and one half or ten inches of water, depending upon the size of float used. The pressure differential was measured according to the mathematical equation

$$M = 10\sqrt{\frac{h}{2.5}} \qquad (1)$$

for the "2½ inch" float, and

$$M = 10\sqrt{\frac{h}{10}} \qquad (2)$$

for the "10 inch" float

where M = recording meter reading

h = pressure differential in inches of water

The circular recording chart had a linear scale from one to ten starting from the inside and running radially to the outside. The metric recording meter proved to be a sensitive instrument for recording small pressure differentials.

III. EXPERIMENTAL TECHNIQUE

For all tests on the cast elbows the equipment was set up as shown in Figure 4. City water was run into a pressure tank to smooth out variations in flow and to subject the water to a definite static pressure. The water was throttled by the discharge valve and the valve on the entrance to the pressure tank. The total amount of flow for each reading of the flow meter was weighed in a weigh tank against time taken with a stop watch. With the use of the pressure tank very little pulsation took place in the manometer. For tests using the recording meter the manometer was replaced with the metric recording meter and the rest of the equipment set up was the same.

For the tests on the long-radius pipe bends the equipment was set up as shown in Figure 5. As the pressure differential in these tests was relatively small, water was used in the manometer. To control the amount of air in the pressure lines leading to the manometer a water reservoir was placed in each pressure line. The water flowing through the pipe bend was weighed against time to determine the rate of flow. The manometer readings were quite steady, especially for the very low rates of flow.

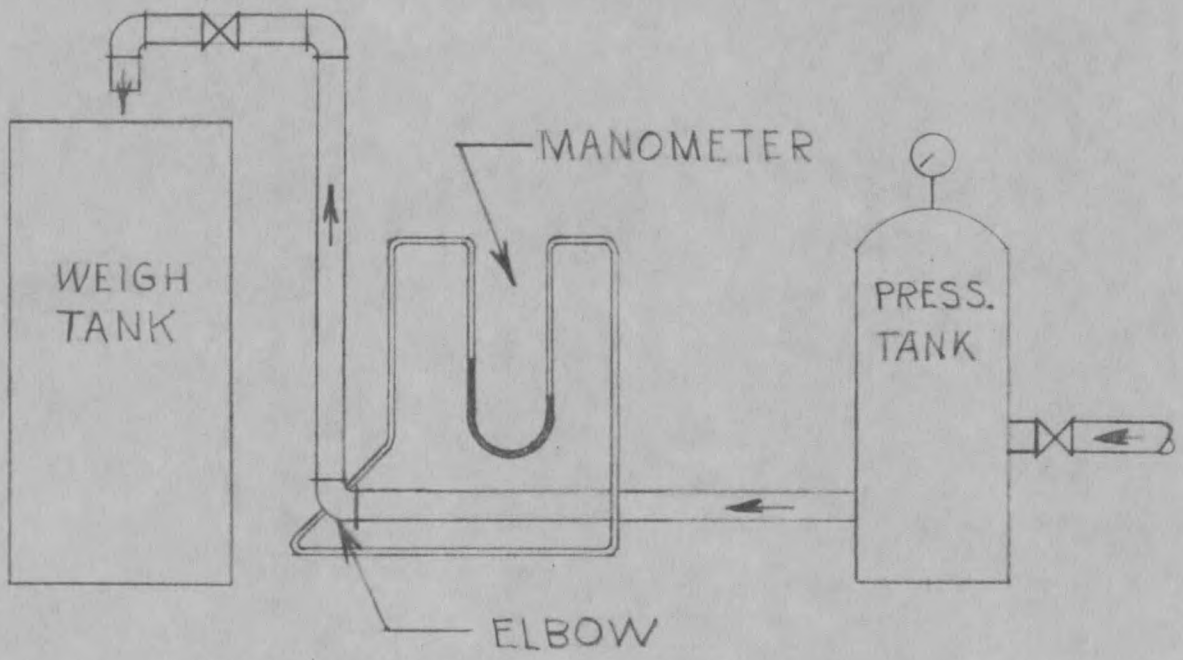

FIGURE 4

APPARATUS ARRANGEMENT FOR TESTS ON THE CAST ELBOWS