THESIS

A STUDY & CALIBRATION

OF

VENTURI WATER METERS

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BY

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Introduction.

This thesis consists of the study and calibration of three Venturi water meters, to determine their coefficients. These meters were designed by J. A. Polson, Ass't Prof. Mech. Eng. and made to determine the boiler feed water at M. A. C. The general plan followed and the apparatus used will be described under separate heads.

Tests were made with a steady pressure securing a very constant flow. Readings were taken under different pressures, beginning with 10 lbs. pressure per square inch and running up to 50 by intervals of 5 and then by intervals of 25 up to 100 lbs. per square inch. Several rates of flow under each pressure head were taken.

Much information concerning the above experiment was obtained from the different engineering magazines and also from the "Transactions of the American Society of Civil and Mechanical Engineers" e. g.

Trans. A. S. C. E. June 1891, "Discussion on Water Meters" by J. Thompson.

Trans. A. S. C. E. Dec. 21, 1887, "Papers Pertaining to Tests on Venturi Meters" by Clemens Herschel.

Trans. A. S. C. E. Vol. 31, 1909, "Tests on Venturi Meter" by Prof. C. M. Allen.

Engineering News, Feb. 28, 1901, "Gauges to be Used with Venturi Meter" by C. P. Spalding.

We are also indebted to Prof. Polson of the Engineering Laboratory for information and help in performing the tests, also to Mr. Crawford for the setting up of the apparatus.

Description of Apparatus.

The apparatus used in performing the tests is shown in the picture attached hereto. The meters were connected up in series to the pressure tank. The first of the tests e. g. 10 & 20 lbs. were run by means of this tank only, this giving a steady head. This consists of a large tank on the fourth floor of Engineering Hall, water being forced up by means of the pump. Bya series of valves on the cylindrical tank in Hydraulic Laberatory shown in the picture ~~and~~ the water is allowed to flow down thru this tank by gravity and thru the meters. The water is allowed to flow in the tank on fourth floor during the entire tests, thus keeping the desired head.

Manometer tubes were made and placed as indicated by the picture. By means of these, the Venturi head and friction losses were determined, the first manometer denoting the Venturi head, the secondthe loss in friction in the particular tube to which it is attached.

At the end of the series of meters was connected a standard meter reading the discharge direct. At the entrance of the first meter was placed a pressure gauge, to determine the pressure at entrance, also one was placed at the end to determing the pressure at the discharge end. These gauges are indicated as No. 1 and No. 2 on the picture.

A valve was inserted in the pipe which connects the meter with the pressure tank, which by means of throttling the desired pressure head was obtainable. A second valve (valve No. 2) was inserted at the pipe leading to the weighing tank.

To each pipe leading to the manometer tubes was placed a

valve. In each of these manometer tubes was placed from eighteen to twenty inches of mercury.

The weighing tank shown in the picture was placed upon the scales and had a capacity of some fifty cubic feet.

Method of Operation

The first two pressures were obtained by means of pumping water to the tank on the fourth floor of Engineering Hall, then throttling the valve to obtain the desired head. The remainder of the tests were run by using the Duplex pump in the Steam Laboratory, pumping the water from the Cedar river direct to the meters, regulating the pressure by means of valve No. 1.

The maximum flow was first obtained by checking the water flowing thru the meter by means of valve No. 2. This valve being placed here in order to regulate the flow, thus keeping the mercury column on the scale, making them readable and also keeping the meters under the desired pressure.

After the maximum flow was obtained the valves leading to manometer tubes were opened, water being allowed to run thru the meters until the mercury columns became steady. The w water was now directed to the weighing tank. Several rates of flow were made upon each head by checking valve No. 2.

While the water was being discharged into the tank five readings were taken on each of the different flows, thus obtaining a fair average of the readings of the mercury columns.

The time in each case varied with the quantity of discharge which depended upon the rate of flow.

The fluctuations of the mercury in the manometer tubes due to unsteadiness of the Duplex pump were overcome by partly filling the pressure chamber in the laboratory with air, the air acting as a cushion, also by means of throttling valves leading to the pressure chamber.

All thermometers, scales and pressure gauges were calibrated.

The scales were found to be correct within a very large range. The thermometer was calibrated by comparing with the standard thermometer No. 28 which itself was correct up to 77° being within limits of temperatures obtained in the tests.

Pressure gauges were calibrated by means of the "Crosby Gauge Tester".

Gauge No. 1 indicating the gauge at entrance and No. 2 the one at the discharge end.

Curves pertaining to calibrations are shown in the appendix.

Formulae and Calculations

To reduce inches of mercury to feet of water taking the unbalanced column of water into account

$$h = \frac{\text{specific gravity} \times H + H}{12}$$

$$h = \frac{H(13.58 - 1)}{12} = 1.05\ H$$

$h = 14.56 \times 1.05 = 15.28$ ft. of water

where H= inches of mercury as read,

h= feet of water

$$q = \frac{W}{w \times t}$$

$$q = \frac{1905}{3 \times 60 \times 62.4} = .1692 \text{ cu. ft. sec.}$$

where q= actual quantity delivered(cu. ft. sec.)

W= actual weight of water

w= unit weight at temperature of water

t= time in seconds

$$Q = \frac{a_1 a_2}{\sqrt{a_2^2 - a_1^2}} \times 8.02\ h$$

$$Q = \frac{.005432 \times .0221}{\sqrt{(.0221)^2 - (.005432)^2}} \times 8.02 \times 15.28 = .1758 \text{ cu. ft. (sec.}$$

where Q= theoretical quantity (cu. ft. sec.)

a_1= area of throat in square feet

a_2= area of inlet in square feet

h= venturi head in feet of water

$$e = \frac{q}{q}$$

$$e = \frac{.1692}{.1758} = .965$$

where e= coefficient.

APPENDIX.

Outline of Thesis

Title: Study and Calibration of Three Venturi Tubes

The object is to calibrate and study the three tubes, to be used in measuring Bailer feed water. The tests to be made in order to determinde the coefficient. Tests to be made with steady pressure, securing a very constant flow.

Owing to the fact that heads greater than 50 lbs cannot be obtained by means of the facilities offered in the Hydraulic Laboratory, therefore the number of readings will be limited to four e. g. 20, 30, 40, and 50 lbs. heads. The rest of the test to be run in the engine room or laberatory , obtaining the desired heads by means of the pump. The heads here are to be 125 lbs. per sq. in. as the highest and then back by intervals of 25 e. g. 125, 100, 75, 50, 25. The meters to be tested were made in the shops. They are to be connected up in series. A pipe is to be connected up with the meters and the tank. In connection with this a standard tube, with manometer attached is to be placed so that a comparison can be made. This standard is to be shifted e. g. inserting it at the ends and then to see the affect if any by changing to another position.

Piezometer tubes or mercury columns where necessary to be inserted into the tubes to obtain the Venturi head and the head due to friction. A valve is to be inserted at the end.

Rates of flow will be run under each head by throttling the valve. The tests are to be made by diverting the discharge

into the weighing tank, one tank being weighed while the other is filling, the duration to be noted as well as the Venturi heads. Readings to be taken every five minutes.

Formula to be used.

W= 60 wact 2 g h

W= actual weight of water from the tank

w= weight of cubic foot at that temperature

a= area Venturi throat

c= coefficient

t= time in minutes

h= Venturi head

$$c = \frac{W}{60\ w\ a\ t\ 2gh}$$

References:

Trans. A. S. C. E. June 1891, "Discussion on Water Meters" by J. Thomson.

Trans. A. S. C. E. Dec. 21, 1887, "Papers Pertaining to Tests on Venturi Meters" by Clemens Herschel.

Trans. A. S. M. E. Vol. 31, 1909, "Tests on Venturi Meters" by Prof. C. M. Allen.

Trans. A. S. M. E. Dec. 1893, "Calibration of a Worthington Water Meter" by John A. Laird.

Engineering News Feb. 28, 1901, "Gauges to be Used With the Venturi Meter" by Charles P. Spalding.

Engineering News Sept. 2, 1882, "Description of Gauges"

Catalogs and other literature were read from Builders Iron Foundry Co. and Simplex Valve and Meter Co. Other small articles were read in Engineering News, Engineering Record , and Engineering Journal.

Final Thesis Time Report.

March 28 to April 7 was spent inreading in the library on the Venturi Meters, tests and general information.

Apr. 7 to APr. 12Fixing pipe for overflow and adjusting Venturi tubes.

Apr. 12, to Apr. 18 tesaning out run-off, calibrating scales.

Apr. 19 Testing out Venturi tubes separately.

Apr. 19, to Apr. 27 Fixing and adjusting tubes to pressure tank, cleaning mercury.

May 3 Began on tests, running on the average of two pressure heads per day.

May 9 Ran 100lb. pressure head.

May 18 to May 20 Tried to run 125lb.

May 22 to May 31 Time was spent on data, writing up, plotting curves, etc.

Total time up to date = 225 hours.

Conclusions.

Many difficulties were encountered in performing this thesis.

Considerable time was spent in repairing the meters, especially meter No. 1. Several sand holds were formed, whereupon water entering would leak thru. The meters were finally set up and arranged as indicated in the picture.

More trouble was encountered with the manometer tubes, the mercury being forced out thru the connections, this however was not encountered until higher pressures were met with. It was our intention first to shift the meters after the first series of tests were run (placing the meter in different series) but owing to the length of time taken in performing the first tests this was impossible.

In comparing the results obtained under the conditions imposed upon us, it can be seen on consulting the data sheets that meter No. 2 is lowest in friction loss, No. 3 and No. 4 following in order. In respect to the coefficients of the three meters, the first meter no doubt is the best, as the coefficients of each flow are all more uniform than in the other two, also lying within limits of coefficients which men of authority have determined.

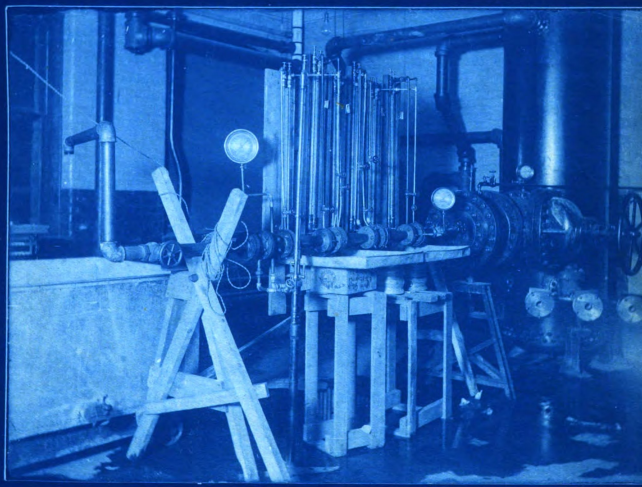
In meter No. 2 the coefficients all vary to a greater extent, but averaging to a reasonable coefficient. In meter No. 2 the coefficients all range above 1.00.

The coefficient of each meter compared with the constant in the formula $c = \frac{a_1 a_2}{\sqrt{a_2^2 - a_1^2}}$ is as follows:

meter	constant	coefficient
No. 1	1.15	.965
No. 2	1.15	1.04
No. 3	1.15	.993

The diameters of each meter were not to dimensions; as indicated on the data sheets.

In general, meter No.1 would be the most desirable to be used.



Venturi Meter No. 1.
Corrected Readings & Coefficients.

Test No.	Head in lbs. Per □" Gauge No. 1	Head in lbs. Per □" Gauge No. 2	Venturi Head in Ft. of Water	Friction Loss Ft. of Water	Temp in F°	Weight of Water per cu. ft.	Time in Minutes	Actual Weight of Water	Standard Cu. Ft. per Sec.	Actual Discharge Cu. Ft. / Sec.	Theoretical Discharge Cu. Ft. / Sec.	Coefficient "C"
	4	1	15.28	3.17	54.2	62.4	3	1905	.147	.1632	.1758	.965

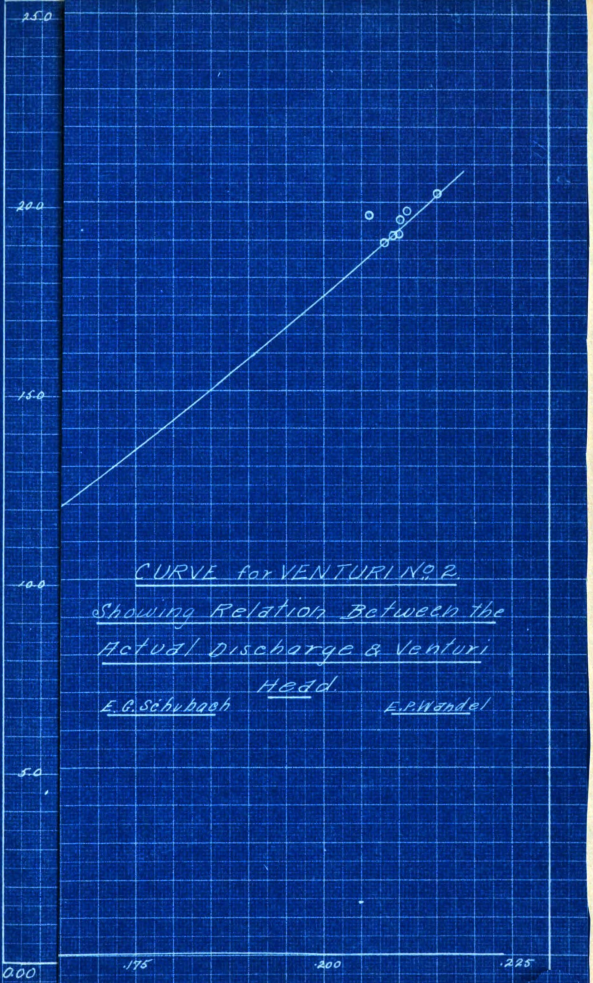
Venturi Meter No 2.
Corrected Readings & Coefficients.

Test No	Head in lbs per □" Gauge No 1	Head in lbs per □" Gauge No 2	Venturi Head Ft. of Water.	Friction Loss in Ft. of Water	Temp in F°	Weight of Water per cu ft.	Time in Minuets	Actual Weight of Water	Standard Cubic Ft. per sec	Actual Discharge Cu ft/sec.	Theoretical Discharge Cu ft/sec	Coefficient "C"
	4	1	13.02	2.27	54.2	62.4	3	1905	.147	.1692	.162	1.04

Venturi Meter No. 3.

Corrected Readings & Coefficients.

Test No.	Head in lbs per □" Gauge No. 1	Head in lbs per □" Gauge No. 2	Venturi Head in Ft. of Water	Friction Loss Ft. of Water	Temp. in F°	Weight of Water per cu ft	Time in Minutes	Actual Weight of Water	Standard cubic Ft. per sec.	Actual Discharge Cu ft/sec	Theoretical Discharge Cu ft/sec	Coefficient "C"



CURVE for VENTURI No. 2.
Showing Relation Between the
Actual Discharge & Venturi
Head.

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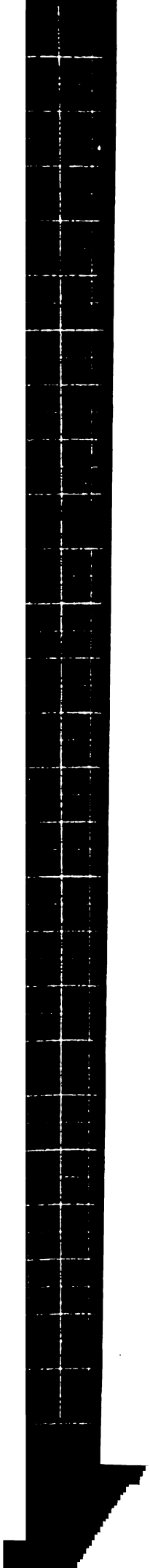
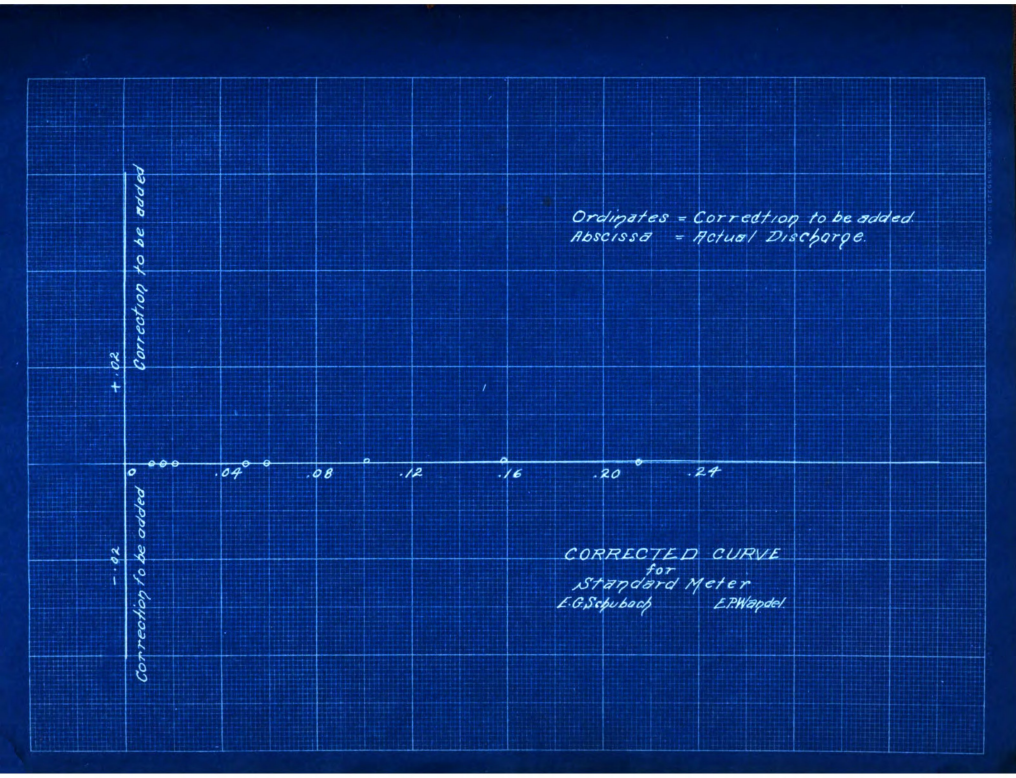
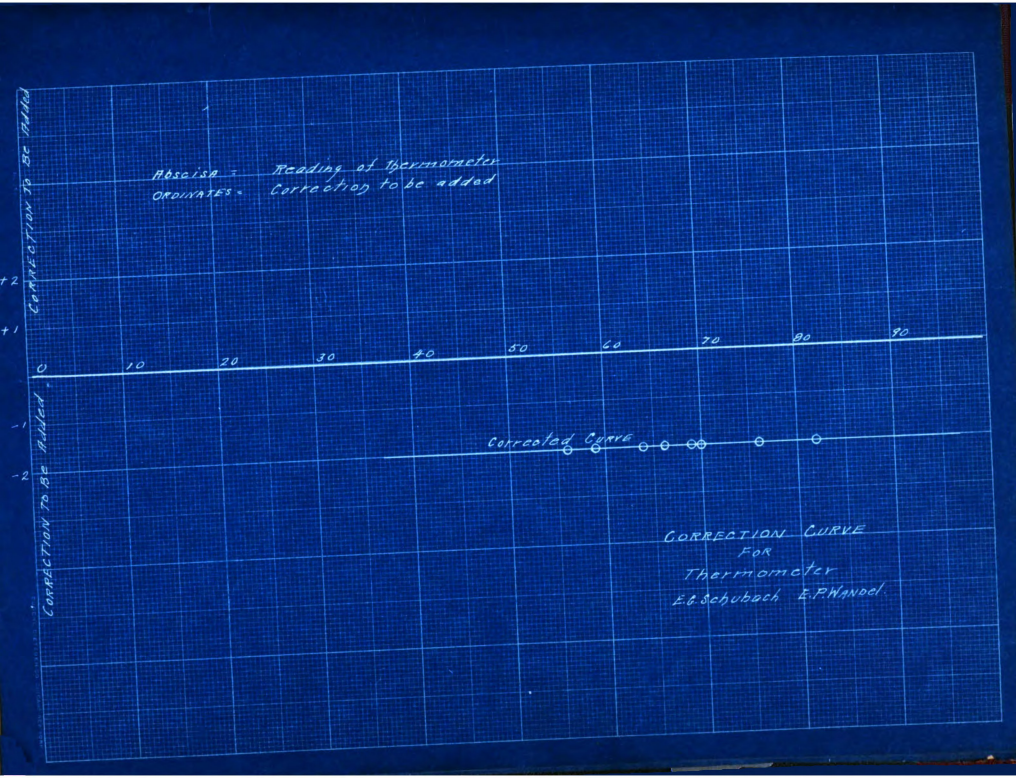
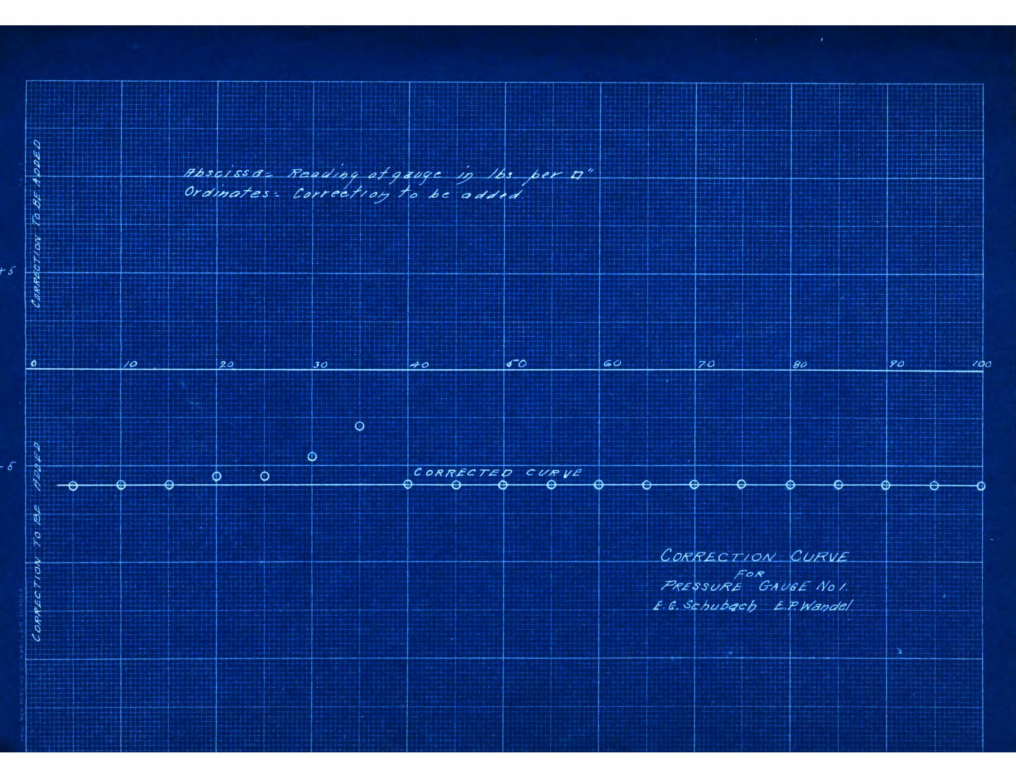
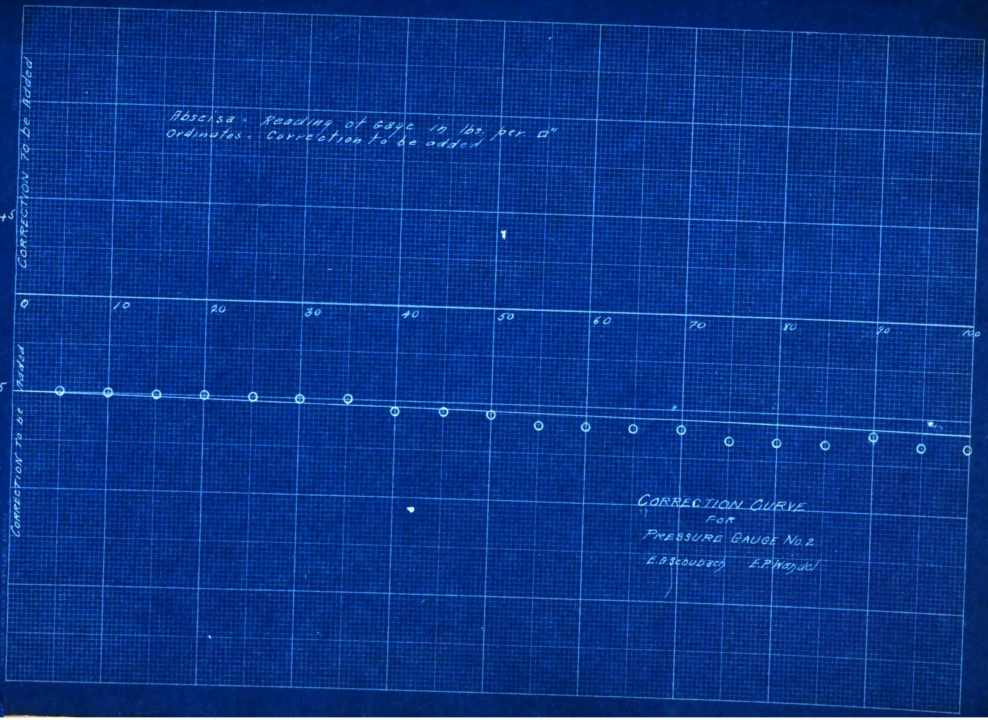



Ordinates = Correction to be added.
Abscissæ = Actual Discharge.
+.02
Correction to be added
0
.04
.08
.12
.16
.20
.24
-.02
Correction to be added
CORRECTED CURVE
for
Standard Meter.
E.G.Schubach
E.P.Wappel


CORRECTION TO BE ADDED
CORRECTION TO BE ADDED
Abscisa = Reading of Thermometer
Ordinates = Correction to be added
+2
+1
0
-1
-2
10
20
30
40
50
60
70
80
90
Corrected Curve
CORRECTION CURVE
FOR
Thermometer
E.G. Schubach E.P. Wandel


Abscissa - Reading of gauge in lbs per □"
Ordinates - Correction to be added
CORRECTION TO BE ADDED
+5
0
10
20
30
40
50
60
70
80
90
100
-5
CORRECTION TO BE ADDED
CORRECTED CURVE
CORRECTION CURVE
FOR
PRESSURE GAUGE No 1.
E.G. Schubach E.P. Wandel


Abscissa: Reading of gage in lbs. per □"
Ordinates: Correction to be added
CORRECTION TO BE ADDED
+5
0
-5
10
20
30
40
50
60
70
80
90
100
CORRECTION CURVE
FOR
PRESSURE GAUGE No. 2.
E.B. Scoudder
E.P. Wright