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# An efficiency test of a laboratory fan

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# AN EFFICIENCY TEST OF A LABORATORY FAN.

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THESIS

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# AN EFFICIENCY TEST OF A LABORATORY FAN.

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## OBJECT OF TESTS

The principal object of these tests is to determine the efficiency of the fan when working against the different sized orifices at various speeds and pressures. Before this could be accomplished, the coefficients of discharge of the 18in., 24in., and 30in., orifices had to be determined.

## NOTATION

$A$ = Area of conduit in square feet.

$A_1$ = Amperes.

$C$ = Coefficient of discharge.

$C_1$ = Coefficient of Pitot Tube.

$D$ = Outside diameter of fan.

$P$ = Average Barometric pressure = 14.16 lb. per sq. in.

$Q$ = Quantity of air in cubic feet per second.

$V$ = Volts.

$W$ = Total weight of air discharged per second.

$T$ = Absolute temperature, Fahrenheit + 460

$a$ = Area of orifice in square feet.

$a_1$ = Equivalent orifice.

$b$ = Breadth of fan, or length of fan blades.

$d$ = Inside diameter of fan.

$d_1$ = Density of one cubic foot of water = 62.5 lb.

$g$ = Acceleration due to gravity in feet per second 32.2.

$h$ = Head of air equivalent to $i_x = \frac{v^2}{2g}$

$i_s$ = Static water gauge pressure

$i_v$ = Velocity water gauge pressure.

$i_T$ = Theoretical water gauge pressure.

$i_{so}$ = Static water gauge pressure in orifice.

$i_x$ = Water gauge pressure equivalent to velocity of approach

$= \frac{v^2}{2g}$

$i_t$ = Total water gauge pressure in orifice.

$n$ = Number of orifices.

$p_s$ = Peripheral speed of fan in feet per sec. $= \frac{\pi d(RPM)}{60}$

$= .157(RPM)$

$p_w$ = Weight of one square foot of water 1 inch deep = 5.2 lb.

$u$ = Units of work in foot lbs.. per second = 550

$v$ = Velocity of air in feet per second ~~in~~ through orifice.

$v_1$ = Velocity of air ~~in~~ through conduit in ft. per second.

$w$ = Weight of one cubic foot of air under existing conditions.

## F O R M U L A E

The following formulae will be used in making the calculations embodied in this thesis, and that they may be better understood a derivation of a few of them is considered advisable. Those that were taken from text-books will contain the reference to the text from which they were taken.

1. Mechanical horsepower, $HP = \frac{VA_{/}}{746}$

(Timbie's Elements of Electricity, page 73.)

2. Theoretical Water Gauges $i_T = \frac{P_s^2 w}{g \, P_w}$

$$i_T = \frac{[.157(RPM)]^2 w}{32.2 \times 5.2} = \frac{[.157(RPM)]^2 w}{167.44}$$

(Reduced from formula (2) par. 15, page 42 vol.37B I.C.S)

3. Ratio of Static to velocity pressure $= \frac{i_s}{i_v}$

4. Velocity of air in feet per second through orifice

$$v = \sqrt{2gh} \qquad h = \frac{(i_s + i_x)d_{/}}{12\,w}$$

$$\text{Then } v = \sqrt{\frac{2gd_{/}(i_s + i_x)}{12\,w}} = \sqrt{\frac{2 \times 32.2 \times 62.5(i_s + i_x)}{12\,w}}$$

$$v = \sqrt{\frac{335(i_s + i_x)}{w}} = 18.3\sqrt{\frac{i_s + i_x}{w}}$$

(Fan Engineering, page 18)

5. Pitot Tube formula $v = 1097\sqrt{\frac{GD}{W}}$ per min.

(Formula furnished by makers)

G = gauge in inches. D = density of liquid

W = weight of cu. ft. of air.

Velocity of air in feet per second through orifice, as measured by Pitot Tube, equals reduction of above formula. $v = C, 18.3\sqrt{\frac{i_v}{W}}$

6. Quantity of air discharged in cubic feet per second $Q = av = \alpha 18.3\sqrt{\frac{i_s}{W}}$ which is the theoretical discharge, the pressure due to velocity of approach and coefficient of discharge being neglected.

Then the actual discharge is $Q = \alpha C 18.3\sqrt{\frac{i_s + i_x}{W}}$

7. Velocity of approach $i_x$. $i_x$ will be so small that (c) can be taken as 0.6 for each size orifice.

$h = \frac{v^2}{2g}$ and $wh = \frac{i_x 62.5}{12}$. Then $i_x = \frac{12\ wh}{62.5}$

$= \frac{12\ w\ v^2}{62.5 \times 2g}$. $v = \frac{Q}{A}$, $Q = \frac{W}{w}$

$W = 0.6184\ d^2\sqrt{\frac{i_s}{T}}$ as developed by R. J. Durley, page 197, vol.27, A.S M.E. $W = .6184\ cnd^2\sqrt{\frac{i_s}{T}}$

Then $i_x = \frac{12\ w\left(\frac{.6184 cnd^2\sqrt{\frac{i_s}{T}}}{Aw}\right)^2}{62.5 \times 2g}$ which reduces to

$i_x = \frac{.000001 n^2 d^4 i_s}{w\ T}$

8. Volumetric Capacity of fan $= \frac{\pi}{4} (D^2 - d^2) \frac{b}{60} (RPM)$

$= \frac{\pi b}{240} (D^2 - d^2)(RPM)$ equals cu. ft. per second.

(Section 14-page 31, vol. 37B I.C.S.)

9. Air horse power equals the total energy of the air in ft. lb. per second divided by the number of ft. lb. per second in one horse power.

$$H.P. = \frac{E}{u} = \left( \frac{Q\ P_w\ i_s + \frac{W\ v^2}{2g}}{u} \right) = \left( \frac{Q\ P_w\ i_s}{u} + \frac{wAv_1^3}{2gu} \right)$$

$P_W \doteq 5.2 \qquad W = wAv \qquad H.P = \left( \frac{Q\ i_s}{105.8} + \frac{wAv_1^3}{35,420} \right)$

10. Mechanical efficiency $= \frac{\text{Air H.P}}{\text{Mechanical H.P.}}$

(Section 15, page 45, vol. 37B - I.C.S.)

11. Manometric efficiency $= \frac{\text{Actual water gauge}}{\text{Theoretical water gauge}} = \frac{i_s}{i_T}$

(section 15, page 44, vol. 37B- I.C.S)

12. The static efficiency is the ratio of the air quantity times the static pressure in inches times 0.000157 ft. lb. divided by the mechanical horsepower,

$= \frac{.000157\ Q\ i_s 60}{\text{Mechanical H.P.}}$

(Fan Engineering page 531)

13. Total efficiency is the ratio of the product of the air quantity times the total pressure in inches times 0.000157 ft. lb. divided by the mechanical horsepower. $= \frac{.000157\ Q\ i_t\ 60}{\text{Mechanical H. P.}}$

(Fan Engineering, page 530)

14. Equivalent orifice. Any orifice discharging air under pressure has a certain resistance which reduces the quantity of air per second flowing through it. This quantity would theoretically flow through a smaller opening which is called the "Equivalent Orifice"

$$Q = aCv = a_1 v = a_1 18.3\sqrt{\frac{i_s + i_x}{w}} \quad \text{then} \quad a_1 = \frac{Q}{18.3\sqrt{\frac{i_s + i_x}{w}}}$$

15. Pitot Tube coefficiency $C_1$. Is the actual velocity of the air flowing thru the orifice per second divided by the velocity as measured by the Pitot Tube.

$$C_1 = \frac{18.3\sqrt{\frac{i_s + i_x}{w}}}{18.3\sqrt{\frac{i_v}{w}}} = \frac{\sqrt{i_s + i_x}}{\sqrt{i_v}} = \sqrt{\frac{i_s + i_x}{i_v}}$$

16. Discharge coefficient

$$C = \frac{\text{Actual discharge}}{\text{Theoretical discharge}}$$

# DESCRIPTION OF APPARATUS

## VENTILATING APPARATUS

### Motor

The fan was driven by a Westinghouse Electric Direct Current Motor, Type SK, shunt wound having a rating of 35 horse power when consuming 230 volts, 128 Amperes and running at 850 revolutions per minute. It is so constructed that it will carry a 56% overload for a short time.

### Fan

The fan was a No. 6 "Sirrocco" made by the American Blower Co., of Detroit, Michigan. It is directly connected to the motor, full housed with left hand single inlet and horizontal bottom discharge.

### Conduit

The conduit was constructed of one inch tongue and grooved pine lumber, built in three air tight sections securely fastened together and connected to the fan as shown in drawing No. 1.

Orifices

The orifice plates were of sheet steel 0.153 inches thick and size shown in drawing No. 2, 3, 4 and 5.

# MEASURING APPARATUS

## Gauges

The ordinary plain glass U-Tube gauge was used to measure the static pressure.

A Pitot Tube and Manometer made by the Davis Instrument Company of Baltimore, Md., was used to measure the velocity ~~of~~ pressure in the plain of the orifices.

## Thermometers

The ordinary Fahrenheit thermometers were used to record the temperature.

## Hygrometer

A plain wet and dry bulb hygrometer made by Queen and Company, was used to determine the percentage moisture saturation of air.

## Barometer

An ordinary mercury barometer, graduated to read to .002 of an inch between 26 and 33 inches, and equipped with a sliding vernier, was used to measure the atmospheric pressure.

# E X P E R I M E N T S

Tests to determine the coefficient of discharge of the 18in., 24in., and 30in., orifices.

## Uniform flow

Before making the runs on any of the orifices, the air current was tested for uniform flow throughout the cross section of the conduit. The current was found to be much stronger in the lower left hand corner than in any other portion of the cross section. To eliminate this, small baffle boards were placed in the intake of the conduit, which gave a fairly even distribution of the current over the total cross section.

## Arrangement of Apparatus

The 3½in., orifice plate of which the coefficient of discharge was known, was bolted between the second and third sections, and the 18in., plate bolted on the end of the conduit. The static pressure gauges were connected to the static pressure pipes which are located immediately behind and in front of each orifice plate. After making the runs with the 18in., orifice it was removed and the 24in., orifice bolted on.

Following the runs on the 24in., orifice, the 30in., orifice was bolted on and runs made ~~up~~on it.

Readings

Accurate readings of the static gauge pressures, the inside and outside temperatures, the hygrometer, the barometer, the voltmeter and ammeter, and the motor revolutions per minute, were taken for each of the seven runs with the 18in., 24in., and 30in., orifices.

## I. TEST WITH $3\frac{1}{2}$IN., ORIFICE ON END OF CONDUIT.

### Arrangement of appartus

The $3\frac{1}{2}$in., orifice plate was bolted on the end of the conduit, the static gauge connected to the static pressure pipes, and the manometer attached to the pitot tube as shown in picture No.1

### Readings

After attaching the plate, the total and static pressure readings were taken in the plane of each opening as shown in picture No.3 . The total pressure readings were then averaged and five holes selected, one in each corner and one in the center of the plate, so that the average of these five readings equaled the average of the 77 readings. The static pressure readings were then averaged in the same manner as the total pressure readings and recorded in table No. 7.

## II. TEST WITH 18in., ORIFICE ON END OF CONDUIT.

### Arrangement of apparatus

The apparatus for the test of the 18in., orifice was arranged the same as for the 3½in. orifice.

Readings

Readings of the total and static pressures were taken in the plane of the orifice at points 1, 2, 3, 4 and 5, as shown in drawing No. 6. The average of each set of five readings was taken as the average total and static pressure, and recorded with the readings of the other instruments for the seven runs as shown in table No. 8.

It was found that the maximum total pressure was uniform over the area of a circle having a radius of 4in., the center being the center of the 18in. circle.

III- TEST WITH 24IN. ORIFICE ON END OF CONDUIT.

Arrangement of apparatus

The arrangement of the apparatus for the runs with the 24in. orifice was the same as that for the 18in. orifice.

Readings

The readings for the seven runs with the 24in. orifice were made in the same manner as those for the 18in., and are recorded in table No.9.

## IV- TEST WITH 30in. ORIFICE ON END OF CONDUIT.

### Arrangement of apparatus

The arrangement of the apparatus for the runs with the 30in. orifice was the same as that for the 18in., and 24in.

### Readings

Total pressure readings were taken in the plane of the 30in. orifice at points 1 to 10 and the average of the 10 readings taken as the average total pressure. It was found that the pressure increased from the top of the orifice down to points No.3 and 4 and then gradually decreased toward the bottom of the orifice. The pressure at the bottom being smaller than at the top. (See drawing No. 6.)

## C A L C U L A T I O N S

### Tables No. 4, 5 and 6.

Columns No. 4 and 5 show the velocity of air in feet per second through the 3½in., and 18in., 24in., and 30in., orifices as calculated by formula No.4

Columns No. 6 and 8 show the theoretical quantity of air in cubic feet per second that can be discharged through the 3½in., and 18in., 24in., and 30in., orifices as calculated by formula No. 6.

Columns No. 7 and 9 show the actual quantity of air in cubic feet per second discharged through the 3½in.and 18in., 24in., and 30in., orifices as calculated by formula No. 6, using Durley's Coefficient of discharge for the 3½in.

Columns No. 10 and 11 show the coefficients of discharge for the 3½in., and 18in., 24in., and 30in., orifices.

### Tables No. 11, 12, 13 and 14

Column No. 3 shows the electrical H. P., being consumed by the motor as calculated by formula No.1.

Column No. 7 shows the theoretical water gauge as calculated by formula No. 2.

Column No. 8, shows the ratio of static to velocity pressures as calculated by formula No. 3.

Column No. 9, shows the water gauge pressure equivalent to the velocity of approach as calculated by formula No.7.

Column No. 10 shows the velocity of air in feet per second through orifice, as calculated by formula No. 4.

Column No. 11, shows the actual quantity of air in cubic feet per second that is discharged through the orifices as calculated by formula No. 6.

Column No. 12, shows the volumetric capcity of the fan running at different speeds as calculated by formula No. 8.

Column No. 13, shows the air horse power developed by the fan when working against the different sized orifices as calculated by formula No. 9.

Column No. 14 shows the mechanical efficiency of the fan as calculated by formula No. 10.

Column No. 15 shows the manometric efficiency as calculated by formula No.11.

Column No. 16 shows the static efficiency of the fan as calculated by formula NO. 12.

Column No. 17 shows the total efficiency of the fan as calculated by formula No. 13.

Column No. 18 shows the size of the equivalent orifices as calculated by formula No. 14.

Column No. 19 shows the Pitot Tube coefficient as calculated by formula No. 15.

Column No. 20 shows the coefficient of discharge for the different sized orifices as calculated by formula No. 16.

Column No. 21 shows the weight of a cubic foot of air in pounds under existing conditions.

# C O N C L U S I O N S

Chart No.1 shows the coefficients of discharge for the 3½in., 18in., 24in., and 30in. orifices. The coefficient for the 3½inch orifice was determined by Professor R. J. Durley of Magill University, Vol. 27, A.S. M. E., and was used as a standard from which the other coefficients were calculated.

The coefficient for the 18 inch orifice as shown by column No.11, table No. 4, and chart No. 1, is too high and varies too much in proportion to the static pressure. This is perhaps due to the inaccurate reading of the water gauge for the 18in. orifice.

The coefficient curve for the 24 inch orifice crosses the curve for the 3½inch orifice near its center, and does not vary so greatly from it, therefore, the coefficient for the 24 inch orifice is perhaps fairly close to what the true coefficient should be.

The coefficient curve for the 3o inch orifice varies more than the curve for the 24 inch orifice, and is therefore not likely to be so nearly correct.

The low efficiencies of the fan are perhaps partly due to the baffle boards in the mouth of the conduit which reduces the area 8.7%, and the wire screen over the intake to the fan which reduces the area 18.7%.

# T A B L E S

Tables 1, 2, 3, 7, 8, 9 and 10 are self explanatory.

Tables 4, 5 and 6 show the calculations made to determine the coefficient of discharge of the 18in., 24in., and 30in. orifices.

Tables 11, 12, 13 and 14 show the calculations made to determine the efficiency of the fan.

Table No. 15 shows the coefficients of discharge for the different size orifices and pressure heads.

Tables No. 1, 2 and 3 show the data taken while making the test runs with the $3\frac{1}{2}$ in., and 18 in., 24 in., and 30 in. orifices.

Specific gravity of liquid used in gauges o.73

| | | | | | Inside - Ther' | | Orifice-is | |
|---|---|---|---|---|---|---|---|---|
| Exp | RPM | Volts | Amp | Bar | Dry | Wet | $3\frac{1}{2}$in. | 18in. |
| 1 | 536 | 220 | 45 | 29.00 | 90 | 70.0 | 0.45 | 3.30 |
| 2 | 569 | 220 | 50 | | 90 | 69.5 | 0.50 | 3.65 |
| 3 | 599 | 220 | 54 | | 90 | 69.5 | o.55 | 4.15 |
| 4 | 612 | 218 | 60 | 29.01 | 90 | 69.5 | 0.60 | 4.55 |
| 5 | 661 | 218 | 66 | | 89 | 68.5 | 0.65 | 4.95 |
| 6 | 684 | 216 | 73 | | 89 | 68.5 | 0.70 | 5.55 |
| 7 | 727 | 216 | 80 | 29.01 | 89 | 68.0 | 0.80 | 6.00 |

TABLE NO.1.

| | | | | | Inside - Ther' | | Orifice-is | |
|---|---|---|---|---|---|---|---|---|
| Exp | RPM | Volts | Amp | Bar. | Dry | Wet | $3\frac{1}{2}$in. | 24in. |
| 1 | 494 | 235 | 53 | 29.01 | 87.5 | 70.0 | o.90 | 2.55 |
| 2 | 504 | 234 | 60 | | 87.5 | 69.0 | 1.10 | 2.85 |
| 3 | 544 | 220 | 65 | | 87.5 | 69.0 | 1.20 | 3.05 |
| 4 | 573 | 220 | 73 | 29.01 | 86.5 | 68.0 | 1.30 | 3.45 |
| 5 | 602 | 218 | 82 | | 86.5 | 68.0 | 1.47 | 3.85 |
| 6 | 655 | 218 | 93 | | 87.0 | 68.5 | 1.58 | 4.25 |
| 7 | 677 | 214 | 106 | 29.01 | 87.0 | 68.5 | 1.88 | 4.85 |

TABLE NO.2.

TABLE NO.3

| No. | RPM | Volts | Amp. | Bar | Inside-Ther' Dry | Wet | Orifice-$i_s$ 3½in. | 30in. |
|---|---|---|---|---|---|---|---|---|
| 1 | 442 | 220 | 57 | 29.01 | 90 | 68 | 1.45 | 1.50 |
| 2 | 471 | 218 | 65 | | 90 | 68 | 1.70 | 1.70 |
| 3 | 503 | 218 | 74 | | 90 | 68 | 1.85 | 2.00 |
| 4 | 537 | 218 | 86 | 29.01 | 89 | 67.5 | 2.15 | 2.30 |
| 5 | 574 | 218 | 98 | | 90 | 67.5 | 2.35 | 2.55 |
| 6 | 603 | 216 | 112 | | 89 | 68 | 2.65 | 2.90 |
| 7 | 650 | 214 | 118 | 29.01 | 89 | 68 | 3.05 | 3.40 |

TABLE NO. 4

Weight of one cu.ft. of air - 0.0698 lb.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| | ($i_s$ + | $i_x$) | Velocities | | Q - 3½in. | | Q - | 18in. | Disch'-C | |
| No. | 3½ | 18 | 3½ | 18 | The'l | Act'l | The'l | Act'l | 3½ | 18 |
| 1 | .34 | 2.42 | 40.5 | 107.2 | 207.3 | 125 | 190.0 | 125 | .599 | .658 |
| 2 | .38 | 2.67 | 42.6 | 112.8 | 219.6 | 131.6 | 199.0 | 131.6 | .599 | .661 |
| 3 | .41 | 3.04 | 44.3 | 120.4 | 228.2 | 136.7 | 212.3 | 136.7 | .599 | .643 |
| 4 | .45 | 3.33 | 46.5 | 124.3 | 239.0 | 143.2 | 220.0 | 143.2 | .599 | .652 |
| 5 | .48 | 3.63 | 48.0 | 131.8 | 246.8 | 147.8 | 231.3 | 147.8 | .599 | .640 |
| 6 | .52 | 4.06 | 49.6 | 140.4 | 256.8 | 153.8 | 247.9 | 153.8 | .599 | .621 |
| 7 | .59 | 4.39 | 53.1 | 145.0 | 273. | 163.8 | 256.0 | 163.8 | .599 | .638 |

## Table No. 5

Weight of one cu. ft. of air = 0.06997 lb.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| | ($i_s$+ $i_x$) | | Velocity | | Q - 3½in | | Q - 24in | | disch -C | |
| No. | 3½ | 24 | 3½ | 24 | The'l | Act'l | The'l | Act'l | 3½ | 24 |
| 1 | .68 | 1.88 | 51.0 | 94.8 | 293.4 | 175.8 | 303.5 | 175.8 | .599 | .578 |
| 2 | .82 | 2.10 | 62.7 | 100.3 | 322.4 | 193.1 | 321.1 | 193.1 | .599 | .601 |
| 3 | .90 | 2.24 | 65.7 | 103.6 | 337.7 | 202.3 | 331.6 | 202.3 | .599 | .610 |
| 4 | .97 | 2.54 | 68.1 | 110.2 | 350.3 | 209.8 | 352.9 | 209.8 | .599 | .595 |
| 5 | 1.09 | 2.83 | 72.2 | 116.2 | 371.3 | 222.4 | 372.4 | 222.4 | .599 | .597 |
| 6 | 1.18 | 3.13 | 75.1 | 122.4 | 386.6 | 231.4 | 391.9 | 231.4 | .599 | .591 |
| 7 | 1.40 | 3.57 | 81.9 | 130.7 | 421.2 | 251.9 | 418.7 | 251.9 | .598 | .602 |

## Table No. 6

Weight of one cu. ft. of air = 0.06964 lb.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| | ($i_s$+ $i_x$) | | Velocity | | Q - 3½in | | Q - 30in | | disch-C | |
| No. | 3½ | 30 | 3½ | 30 | The'l | Act'l | The'l | Act'l | 3½ | 30 |
| 1 | 1.08 | 1.12 | 72.1 | 73.4 | 370.9 | 222.2 | 360.5 | 222.2 | .599 | .616 |
| 2 | 1.27 | 1.27 | 78.2 | 78.2 | 402.2 | 240.9 | 383.9 | 240.9 | .599 | .628 |
| 3 | 1.38 | 1.49 | 81.5 | 84.7 | 419.2 | 250.7 | 415.8 | 250.7 | .598 | .603 |
| 4 | 1.67 | 1.71 | 87.9 | 90.6 | 452.1 | 270.5 | 444.9 | 270.5 | .598 | .609 |
| 5 | 1.74 | 1.90 | 91.5 | 95.6 | 470.7 | 281.5 | 469.5 | 281.5 | .598 | .599 |
| 6 | 1.97 | 2.16 | 97.2 | 102.8 | 500.1 | 298.5 | 499.8 | 298.5 | .597 | .597 |
| 7 | 2.27 | 2.53 | 104.4 | 110.2 | 537.0 | 320.6 | 541.2 | 320.6 | .597 | .592 |

Table No. 7 shows the data taken while making the test runs on the $3\frac{1}{2}$ inch orifice.

Specific gravity of liquid used in gauge - 0.73

| No. | RPM. | Volts | Amp. | Bar | Inside Ther' Dry | Inside Ther' Wet |
|---|---|---|---|---|---|---|
| 1 | 421 | 222 | 63 | 28.95 | 80 | 61 |
| 2 | 439 | 220 | 71 | 28.952 | 76 | 58.5 |
| 3 | 466 | 220 | 81 | 28.952 | 75 | 57.5 |
| 4 | 515 | 220 | 94 | 28.952 | 74 | 56.5 |
| 5 | 530 | 218 | 107 | 28.936 | 74 | 56 |
| 6 | 565 | 216 | 124 | 28.936 | 74 | 56 |
| 7 | 611 | 214 | 146 | 28.922 | 73.5 | 55.5 |

| No. | outside Temp. | $i_s$ | $i_t$ | $i_{so}$ | $i_v$ |
|---|---|---|---|---|---|
| 1 | 74 | 1.80 | 2.01 | 0.98 | 1.03 |
| 2 | 73 | 2.00 | 2.21 | 1.12 | 1.09 |
| 3 | 72 | 2.30 | 2.53 | 1.26 | 1.27 |
| 4 | 72 | 2.65 | 2.90 | 1.45 | 1.45 |
| 5 | 72 | 3.00 | 3.26 | 1.59 | 1.67 |
| 6 | 71 | 3.50 | 3.73 | 1.97 | 1.76 |
| 7 | 71 | 3.90 | 4.29 | 2.13 | 2.16 |

Table No. 8 shows the data taken while making test runs on the 18 inch orifice.

Specific gravity of liquid used in gauges - 0.73

| No. | RPM. | Volts | Amp. | Bar | Inside-Ther. Dry | Wet |
|---|---|---|---|---|---|---|
| 1 | 539 | 220 | 44 | 29.028 | 77 | 59.5 |
| 2 | 600 | 220 | 50 | 29.028 | 78 | 59.5 |
| 3 | 614 | 220 | 55 | 29.028 | 78 | 59 |
| 4 | 641 | 220 | 60 | 29.018 | 78 | 59 |
| 5 | 675 | 220 | 68 | 29.028 | 78 | 59 |
| 6 | 719 | 220 | 75 | 29.020 | 79 | 59 |
| 7 | 741 | 220 | 83 | 29.020 | 79 | 59 |

| No. | Outside Temp. | $i_s$ | $i_t$ | $i_{so}$ | $i_v$ |
|---|---|---|---|---|---|
| 1 | 80 | 3.70 | 3.59 | 2.0 | 1.59 |
| 2 | 81 | 4.25 | 4.05 | 2.45 | 1.60 |
| 3 | 81 | 4.65 | 4.58 | 2.80 | 1.78 |
| 4 | 82 | 5.20 | 5.08 | 3.10 | 1.98 |
| 5 | 82 | 5.80 | 5.69 | 3.50 | 2.19 |
| 6 | 83 | 6.25 | 6.27 | 3.65 | 2.62 |
| 7 | 83 | 6.90 | 6.78 | 4.10 | 2.68 |

Table No. 9 shows the data taken while making the test runs on the 24 inch **ofifice.**

Specific gravity of liquid used in gauges = 0.73

| No. | RPM. | Volts | Amp. | Bar | Inside-Ther: Dry | Wet |
|---|---|---|---|---|---|---|
| 1 | 473 | 220 | 51 | 28.76 | 83 | 69.5 |
| 2 | 506 | 218 | 58 | 28.766 | 83.5 | 70.0 |
| 3 | 540 | 218 | 65 | 28.766 | 83 | 69 |
| 4 | 572 | 216 | 73 | 28.772 | 82 | 68 |
| 5 | 605 | 216 | 82 | 28.774 | 82 | 67.5 |
| 6 | 636 | 214 | 94 | 28.776 | 82 | 67 |
| 7 | 677 | 210 | 105 | 28.772 | 883 | 67.5 |

| No. | Outside Temp. | $i_s$ | $i_t$ | $i_{so}$ | $i_v$ |
|---|---|---|---|---|---|
| 1 | 85 | 2.90 | 3.00 | 1.75 | 1.25 |
| 2 | 85 | 3.30 | 3.32 | 2.0 | 1.32 |
| 3 | 83 | 3.80 | 3.88 | 2.30 | 1.58 |
| 4 | 83 | 4.30 | 4.37 | 2.60 | 1.77 |
| 5 | 83 | 4.70 | 4.85 | 2.90 | 1.95 |
| 6 | 84 | 5.30 | 5.24 | 3.20 | 2.04 |
| 7 | 84 | 6.00 | 6.05 | 3.70 | 2.35 |

Table No. 10 shows the data taken while making the test runs on the 30 inch orifice.

Specific gravity of liquid used in gauges = 0.73

| No. | RPM. | Volts | Amp. | Bar | Inside-Ther. Dry | Inside-Ther. Wet |
|---|---|---|---|---|---|---|
| 1 | 427 | 227 | 50 | 29.014 | 84 | 64 |
| 2 | 464 | 227 | 70 | 29.014 | 80 | 61 |
| 3 | 488 | 227 | 81 | 29.012 | 79.5 | 60 |
| 4 | 520 | 225 | 92 | 29.010 | 79 | 60 |
| 5 | 557 | 222 | 107 | 29.016 | 79 | 60 |
| 6 | 591 | 220 | 122 | 29.014 | 79 | 59.5 |
| 7 | 630 | 218 | 138 | 29.012 | 78.5 | 59 |

| No. | Outside Temp. | $i_s$ | $i_t$ | $i_{so}$ | $i_v$ |
|---|---|---|---|---|---|
| 1 | 84 | 2.0 | 2.15 | 1.15 | 1.00 |
| 2 | 84 | 2.25 | 2.35 | 1.30 | 1.05 |
| 3 | 83 | 2.50 | 2.59 | 1.50 | 1.09 |
| 4 | 83 | 2.90 | 2.95 | 1.70 | 1.25 |
| 5 | 83 | 3.20 | 3.32 | 1.95 | 1.37 |
| 6 | 82 | 3.70 | 3.77 | 2.10 | 1.67 |
| 7 | 82 | 4.20 | 4.32 | 2.35 | 2.00 |

## TABLE NO. 11.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| No | RPM | H.P | $i_v$ | $i_s$ | $i_t$ | $i_T$ | $\frac{i_s}{I_v}$ | $i_x$ | v | Q |
| 1 | 421 | 18.8 | 0.75 | 1.31 | 1.47 | 1.85 | 1.73 | .03 | 79.5 | 245 |
| 2 | 439 | 20.9 | 0.80 | 1.46 | 1.61 | 2.02 | 1.83 | .03 | 83.5 | 257 |
| 3 | 466 | 23.9 | 0.93 | 1.68 | 1.85 | 2.09 | 1.81 | .04 | 89.5 | 276 |
| 4 | 515 | 27.7 | 1.06 | 1.94 | 2.12 | 2.80 | 1.83 | .04 | 96.0 | 296 |
| 5 | 530 | 31.3 | 1.22 | 2.19 | 2.38 | 2.96 | 1.80 | .05 | 102.0 | 314 |
| 6 | 565 | 35.9 | 1.29 | 2.56 | 2.72 | 3.30 | 1.99 | .06 | 108.7 | 335 |
| 7 | 611 | 41.9 | 1.58 | 2.85 | 3.13 | 3.94 | 1.81 | .06 | 116.4 | 359 |

| 1 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Vol Cap | Air H.P. | Mech' Eff' | Man' Eff' | Stat' Eff' | Total Eff' | Equiv' Orif' | $C_1$ | C | w |
| 1 | 19.2 | 3.50 | 19 | 71 | 16.1 | 18.1 | 3.08 | 1.314 | .599 | .07091 |
| 2 | 20.0 | 3.93 | 19 | 72 | 16.7 | 18.6 | 3.07 | 1.352 | .598 | .07147 |
| 3 | 21.3 | 4.86 | 20 | 73 | 18.3 | 20.1 | 3.08 | 1.343 | .598 | .07173 |
| 4 | 23.5 | 6.01 | 22 | 70 | 19.5 | 21.3 | 3.08 | 1.353 | .597 | .07181 |
| 5 | 24.3 | 7.25 | 23 | 74 | 21.0 | 22.5 | 3.07 | 1.340 | .597 | .07178 |
| 6 | 25.8 | 8.96 | 25 | 78 | 22.5 | 23.9 | 3.08 | 1.408 | .596 | .07178 |
| 7 | 27.9 | 10.73 | 26 | 72 | 23.0 | 25.3 | 3.08 | 1.343 | .596 | .07181 |

$3\frac{1}{2}$ in. orifice calculations.

## TABLE NO. 12

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| No | RPM | H.P | $i_v$ | $i_s$ | $i_t$ | $i_T$ | $\frac{i_s}{i_v}$ | $i_x$ | $v$ | Q |
| 1 | 539 | 13.0 | 1.16 | 2.72 | 2.62 | 3.07 | 2.35 | .01 | 115.3 | 130.5 |
| 2 | 600 | 14.7 | 1.17 | 3.13 | 2.96 | 3.55 | 2.67 | .01 | 121.4 | 137.9 |
| 3 | 614 | 16.2 | 1.30 | 3.39 | 3.35 | 3.98 | 2.61 | .01 | 126.3 | 142.1 |
| 4 | 641 | 17.7 | 1.44 | 3.79 | 3.71 | 4.30 | 2.63 | .01 | 133.5 | 148.3 |
| 5 | 675 | 20.1 | 1.60 | 4.24 | 4.15 | 4.53 | 2.65 | .01 | 141.3 | 155.5 |
| 6 | 719 | 22.1 | 1.91 | 4.56 | 4.57 | 5.46 | 2.39 | .01 | 146.6 | 160.3 |
| 7 | 741 | 24.5 | 1.96 | 5.04 | 4.95 | 5.77 | 2.57 | .01 | 154.1 | 167.4 |

| 1 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Vol Cap | Air H.P. | Mech Eff' | Man' Eff' | Stat' Eff' | Total Eff' | Equiv' Orif' | $C_1$ | C | w |
| 1 | 24.6 | 3.91 | 30 | 89 | 26.3 | 24.7 | 1.14 | 1.531 | .651 | .07144 |
| 2 | 27.4 | 4.52 | 31 | 88 | 27.6 | 26.2 | 1.13 | 1.636 | .643 | .07132 |
| 3 | 28.1 | 5.14 | 32 | 85 | 28.0 | 27.8 | 1.12 | 1.615 | .637 | .07131 |
| 4 | 29.3 | 5.94 | 34 | 88 | 29.9 | 29.3 | 1.11 | 1.622 | .629 | .07131 |
| 5 | 30.8 | 7.00 | 35 | 94 | 30.9 | 30.2 | 1.10 | 1.628 | .623 | .07131 |
| 6 | 32.9 | 7.77 | 35 | 84 | 31.4 | 31.4 | 1.09 | 1.545 | .619 | .07123 |
| 7 | 33.9 | 8.94 | 36 | 87 | 32.5 | 31.9 | 1.08 | 1.604 | .615 | .07123 |

18in. orifice calculations.

## TABLE NO. 13

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| No | RPM | H.P | $i_v$ | $i_s$ | $i_t$ | $i_T$ | $\frac{i_s'}{i_v}$ | $i_x$ | v | Q |
| 1 | 473 | 15.0 | 0.91 | 2.12 | 2.20 | 2.30 | 2.33 | .02 | 100.9 | 194 |
| 2 | 506 | 16.9 | 0.96 | 2.41 | 2.42 | 2.63 | 2.51 | .02 | 107.6 | 206 |
| 3 | 540 | 19.0 | 1.15 | 2.78 | 2.82 | 2.99 | 2.42 | .03 | 115.5 | 220 |
| 4 | 572 | 21.1 | 1.29 | 3.14 | 3.19 | 3.36 | 2.44 | .03 | 122.8 | 230 |
| 5 | 605 | 23.7 | 1.42 | 3.43 | 3.54 | 3.76 | 2.42 | .03 | 128.3 | 242 |
| 6 | 636 | 27.0 | 1.49 | 3.87 | 3.82 | 4.16 | 2.60 | .03 | 136.2 | 255 |
| 7 | 677 | 29.6 | 1.71 | 4.38 | 4.42 | 4.72 | 2.56 | .04 | 144.9 | 269 |

| 1 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Vol Cap | Air H.P | Mech' Eff' | Man' Eff' | Stat' Eff' | Total Eff' | Equiv' Orif' | $C_1$ | C | w |
| 1 | 21.6 | 4.14 | 27 | 92 | 25.7 | 26.6 | 1.92 | 1.525 | .601 | .06984 |
| 2 | 23.1 | 4.89 | 29 | 92 | 27.6 | 27.7 | 1.91 | 1.585 | .598 | .06977 |
| 3 | 24.7 | 6.01 | 32 | 93 | 30.2 | 30.6 | 1.90 | 1.555 | .594 | .06986 |
| 4 | 26.1 | 7.11 | 33 | 93 | 32.2 | 32.8 | 1.87 | 1.560 | .592 | .06985 |
| 5 | 27.6 | 8.17 | 34 | 91 | 32.9 | 33.9 | 1.88 | 1.554 | .589 | .06986 |
| 6 | 29.1 | 9.73 | 36 | 93 | 34.5 | 34.1 | 1.87 | 1.612 | .585 | .06990 |
| 7 | 30.9 | 11.82 | 39 | 93 | 37.6 | 38.9 | 1.86 | 1.606 | .580 | .06991 |

24in. orifice calculations.

# TABLE NO. 14

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| No | RPM | H.P | $i_v$ | $i_s$ | $i_t$ | $i_T$ | $\frac{i_s}{i_v}$ | $i_x$ | $\upsilon$ | Q |
| 1 | 427 | 18.29 | 0.73 | 1.46 | 1.57 | 1.89 | 2.00 | .03 | 83.29 | 249.0 |
| 2 | 464 | 21.30 | 0.77 | 1.64 | 1.72 | 2.25 | 2.13 | .03 | 87.99 | 261.8 |
| 3 | 488 | 24.65 | 0.80 | 1.82 | 1.89 | 2.50 | 2.27 | .04 | 92.56 | 274.1 |
| 4 | 520 | 27.75 | 0.91 | 2.12 | 2.15 | 2.84 | 2.33 | .04 | 100.00 | 293.1 |
| 5 | 557 | 31.84 | 1.00 | 2.34 | 2.42 | 3.25 | 2.34 | .05 | 105.1 | 307.4 |
| 6 | 591 | 35.98 | 1.22 | 2.70 | 2.75 | 3.66 | 2.22 | .06 | 112.8 | 326.7 |
| 7 | 630 | 40.33 | 1.46 | 3.06 | 3.16 | 4.16 | 2.09 | .06 | 120.1 | 344.3 |

| 1 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Vol Cap | Air H.P | Mech' Eff' | Man' Eff' | Stat' Eff' | Total Eff' | Equiv' Eff' | $C_1$ | C | w |
| 1 | 19.5 | 3.77 | 20 | 77 | 18.7 | 20.2 | 2.99 | 1.440 | .609 | .07062 |
| 2 | 21.2 | 4.44 | 20 | 73 | 19.0 | 19.8 | 2.97 | 1.459 | .606 | .07107 |
| 3 | 22.3 | 5.17 | 21 | 73 | 19.1 | 19.7 | 2.96 | 1.508 | .603 | .07129 |
| 4 | 23.8 | 6.45 | 23 | 74 | 21.1 | 21.4 | 2.93 | 1.526 | .597 | .07128 |
| 5 | 25.4 | 7.46 | 23 | 72 | 21.3 | 22.0 | 2.92 | 1.530 | .596 | .07116 |
| 6 | 27.0 | 9.18 | 25 | 74 | 23.1 | 23.4 | 2.90 | 1.490 | .590 | .07124 |
| 7 | 28.8 | 10.95 | 27 | 73 | 24.6 | 25.4 | 2.87 | 1.448 | .584 | .07121 |

30 inch orifice calculations.

## TABLE NO. 15

Table No. 15 shows the coefficients of discharge for orifices from 5/16 inches to 4½ inches diameter as determined by Professor R. J. Durley at Magill University, and the 18in., 24in., and 3o inch as determined by Blaylock, Schroer and Miller at the Missouri School of Mines and Metallurgy.

| Diameter of orifice | 1-Inch Head | 2-Inch Head | 3-Inch Head | 4-Inch Head | 5-Inch Head |
|---|---|---|---|---|---|
| 5/16in. | 0.603 | 0.606 | 0.610 | 0.613 | 0.613 |
| 1/2in. | 0.602 | 0.605 | 0.608 | 0.610 | 0.613 |
| 1 in. | 0.601 | 0.603 | 0.605 | 0.606 | 0.607 |
| 1 1/2in. | 0.601 | 0.601 | 0.602 | 0.603 | 0.603 |
| 2 in. | 0.600 | 0.600 | 0.600 | 0.600 | 0.600 |
| 2 1/2in. | 0.599 | 0.599 | 0.599 | 0.598 | 0.598 |
| 3 in. | 0.599 | 0.598 | 0.597 | 0.596 | 0.596 |
| 3 1/2in. | 0.599 | 0.597 | 0.596 | 0.595 | 0.594 |
| 4 in. | 0.598 | 0.597 | 0.595 | 0.594 | 0.593 |
| 4 1/2in. | 0.598 | 0.596 | 0.594 | 0.593 | 0.592 |
| 18in. | 0.690 | 0.665 | 0.645 | 0.625 | 0.615 |
| 24in. | 0.612 | 0.602 | 0.593 | 0.584 | 0.575 |
| 30in. | 0.616 | 0.600 | 0.585 | 0.570 | 0.555 |

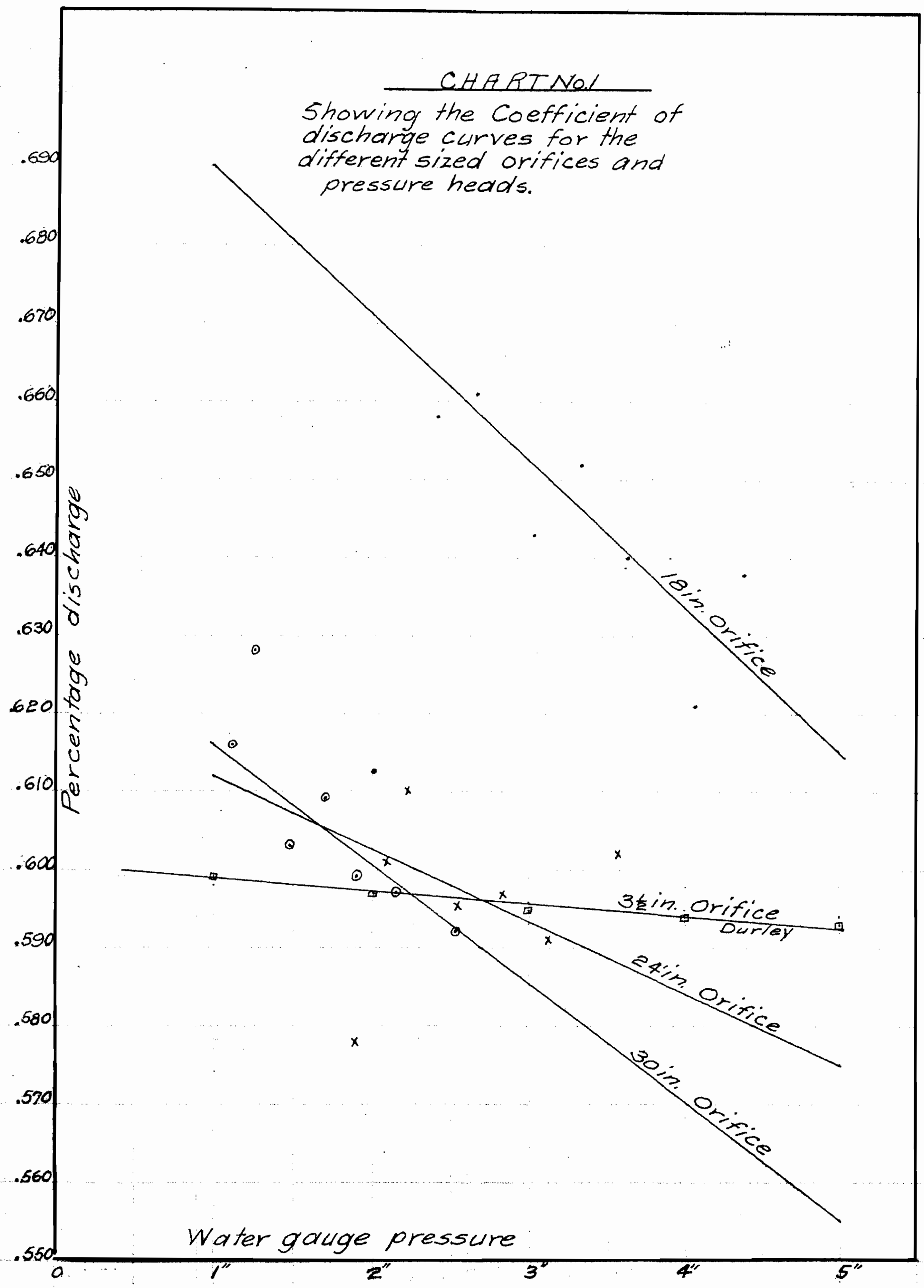


CHART No. 1
Showing the Coefficient of discharge curves for the different sized orifices and pressure heads.
.690
.680
.670
.660
.650
.640
.630
.620
.610
.600
.590
.580
.570
.560
.550
Percentage discharge
18 in. Orifice
3½ in. Orifice
Durley
24 in. Orifice
30 in. Orifice
Water gauge pressure
0
1"
2"
3"
4"
5"

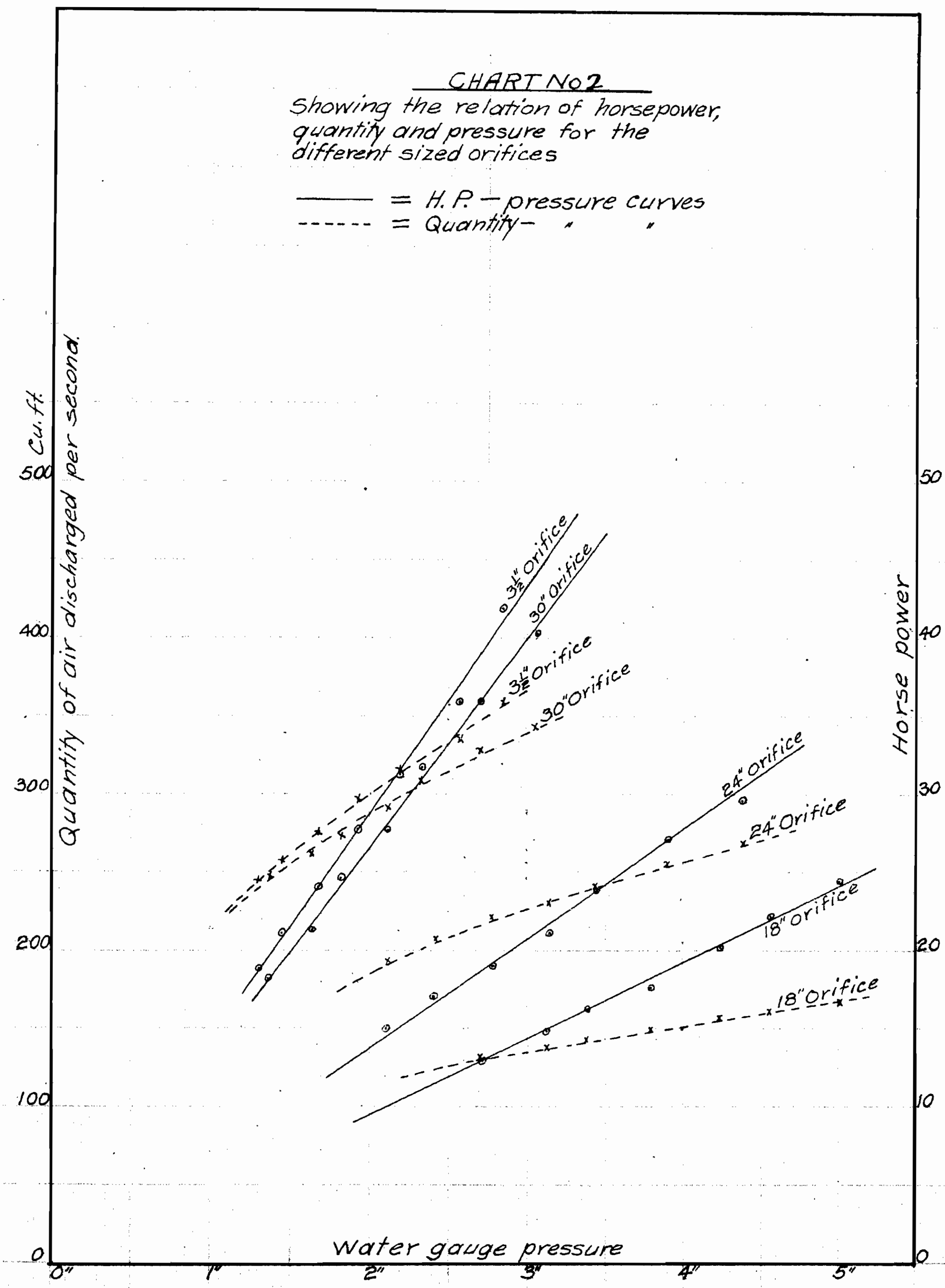


CHART No 2
Showing the relation of horsepower, quantity and pressure for the different sized orifices
——— = H. P. — pressure curves
------ = Quantity— " "
Cu. ft.
Quantity of air discharged per second.
Horse power
Water gauge pressure
0
100
200
300
400
500
10
20
30
40
50
0"
1"
2"
3"
4"
5"
3½" Orifice
30" Orifice
3½" Orifice
30" Orifice
24" Orifice
24" Orifice
18" Orifice
18" Orifice

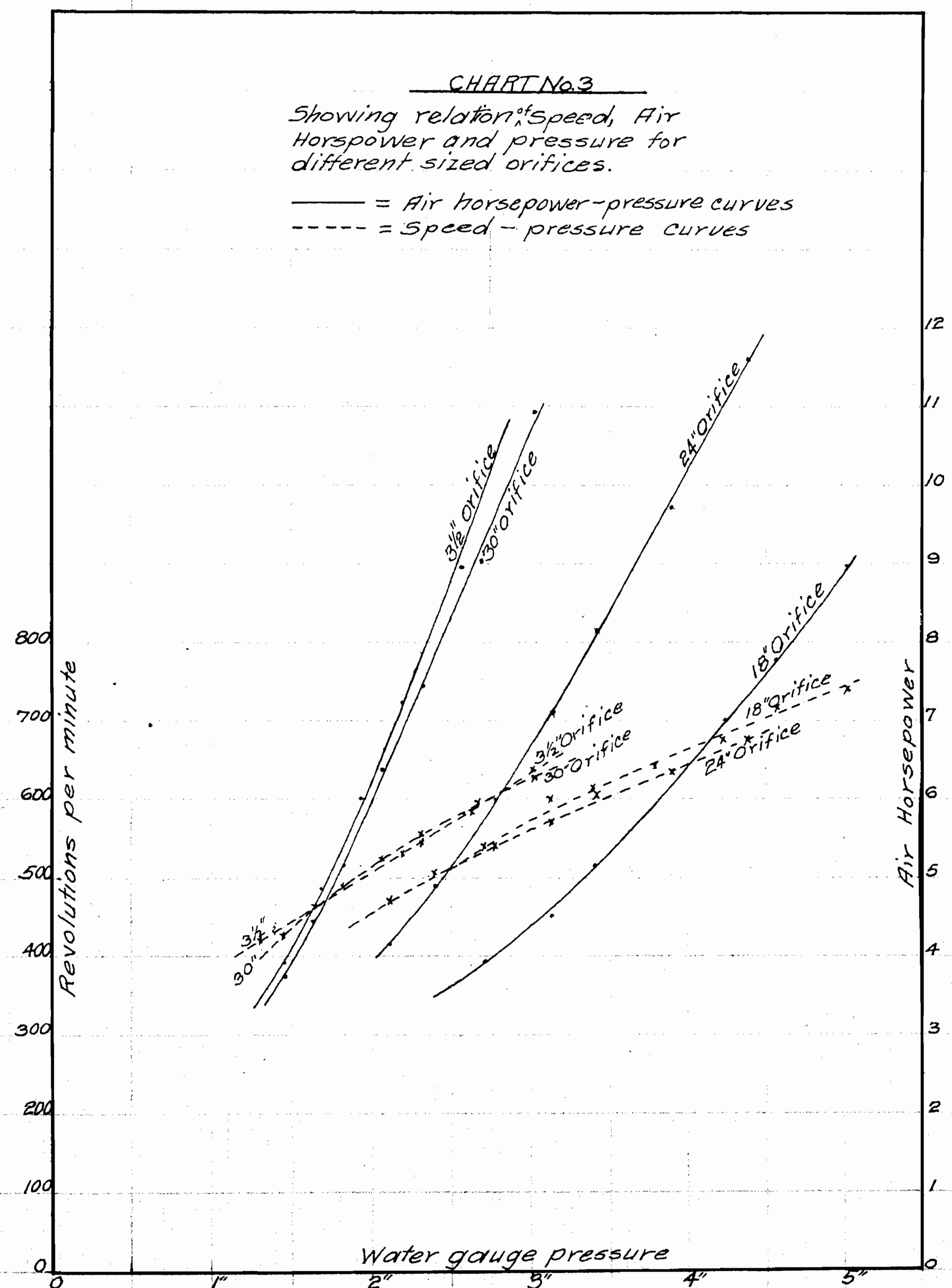


CHART No. 3
Showing relation of Speed, Air Horsepower and pressure for different sized orifices.
——— = Air horsepower-pressure curves
- - - - = Speed - pressure curves
3½" Orifice
30" Orifice
24" Orifice
18" Orifice
3½" Orifice
30" Orifice
18" Orifice
24" Orifice
3½"
30"
Revolutions per minute
Air Horsepower
Water gauge pressure
0
100
200
300
400
500
600
700
800
1
2
3
4
5
6
7
8
9
10
11
12
1"
2"
3"
4"
5"

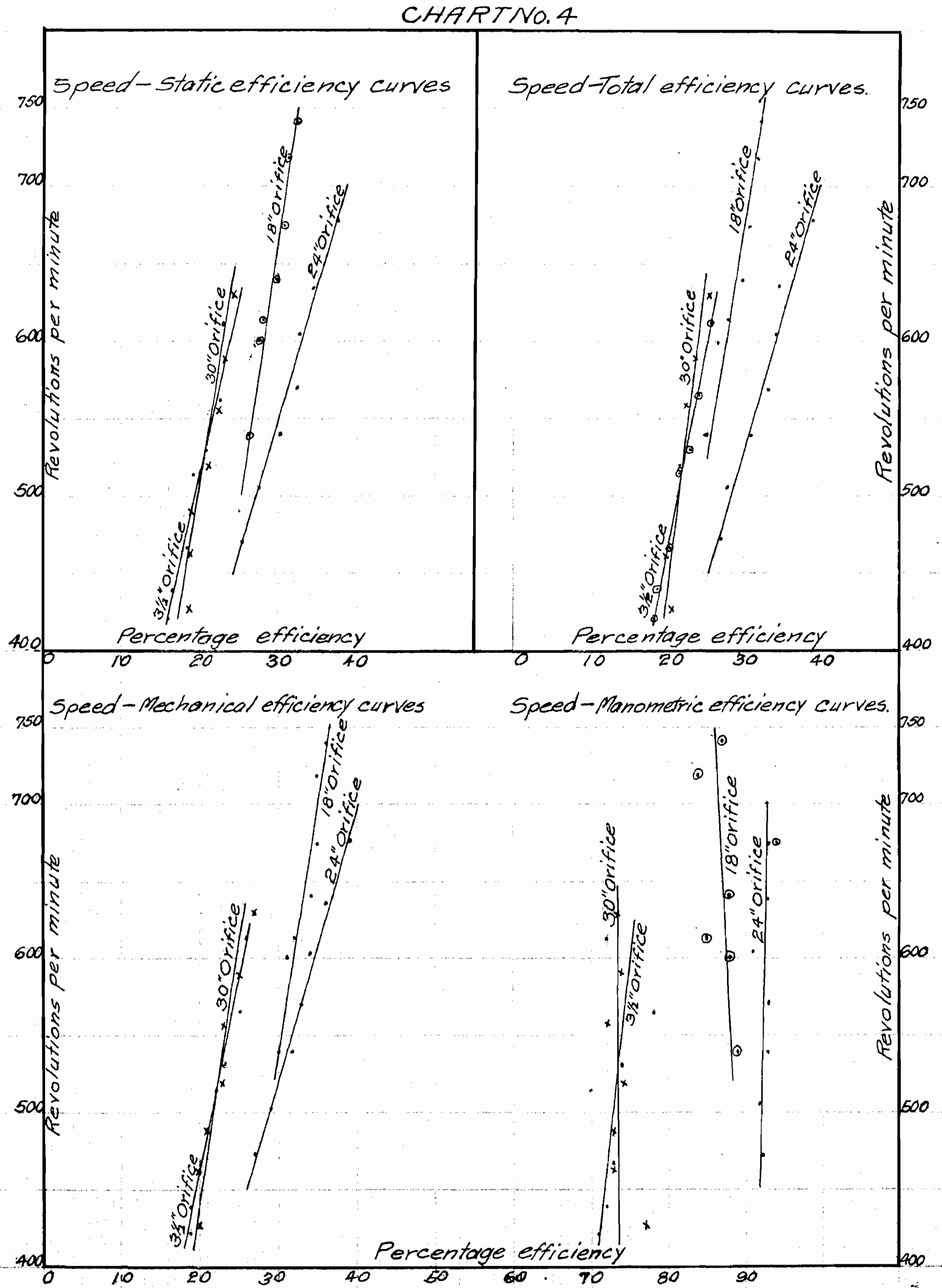


CHART No. 4
Speed-Static efficiency curves
Speed-Total efficiency curves.
Speed-Mechanical efficiency curves
Speed-Manometric efficiency curves.
Revolutions per minute
Percentage efficiency
3½" Orifice
30" Orifice
18" Orifice
24" Orifice
750
700
600
500
400
0
10
20
30
40
50
60
70
80
90

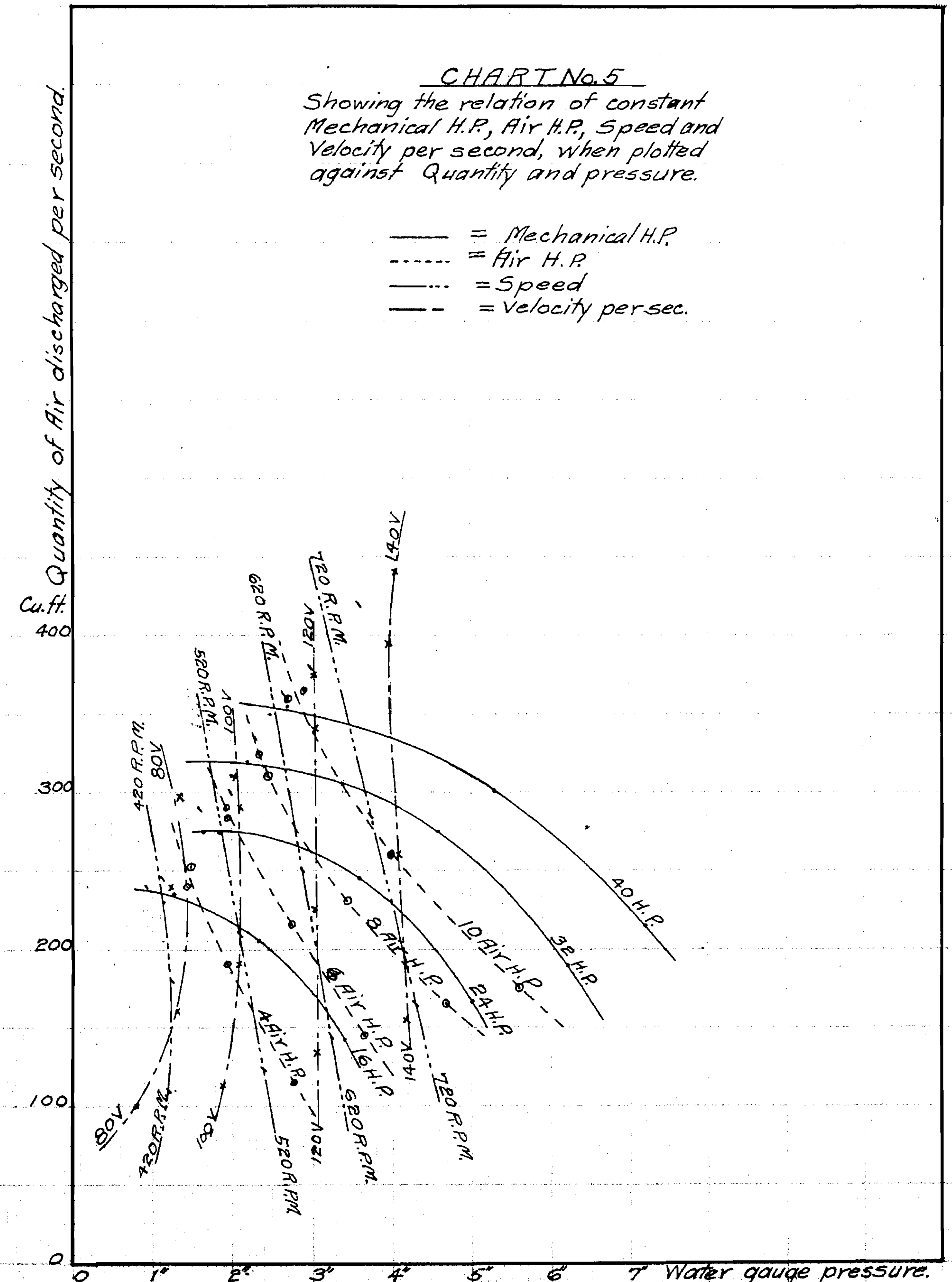
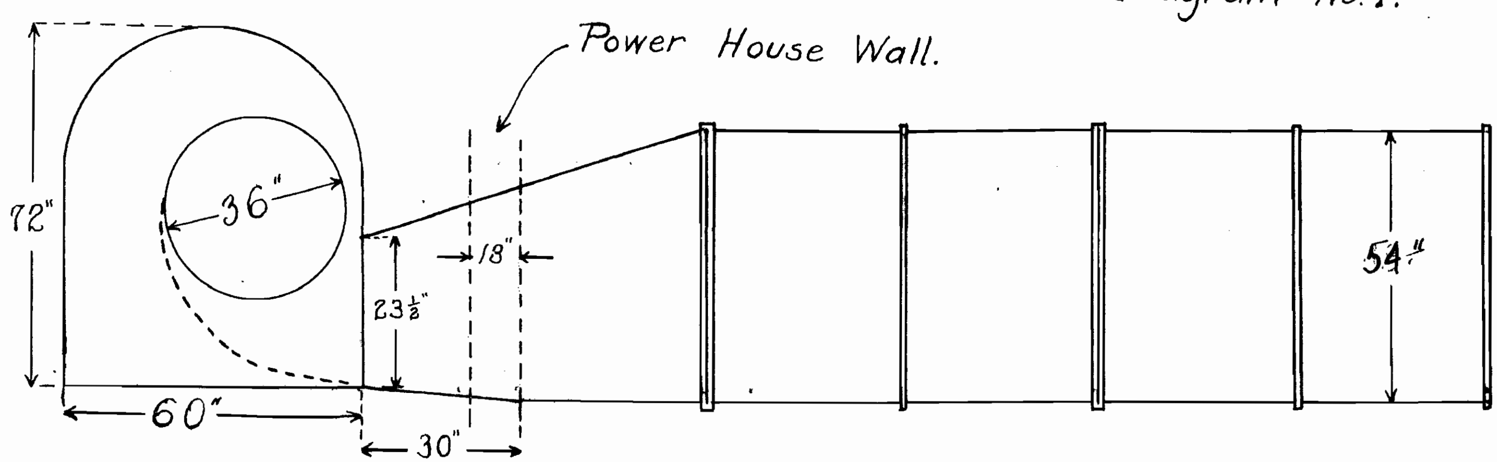


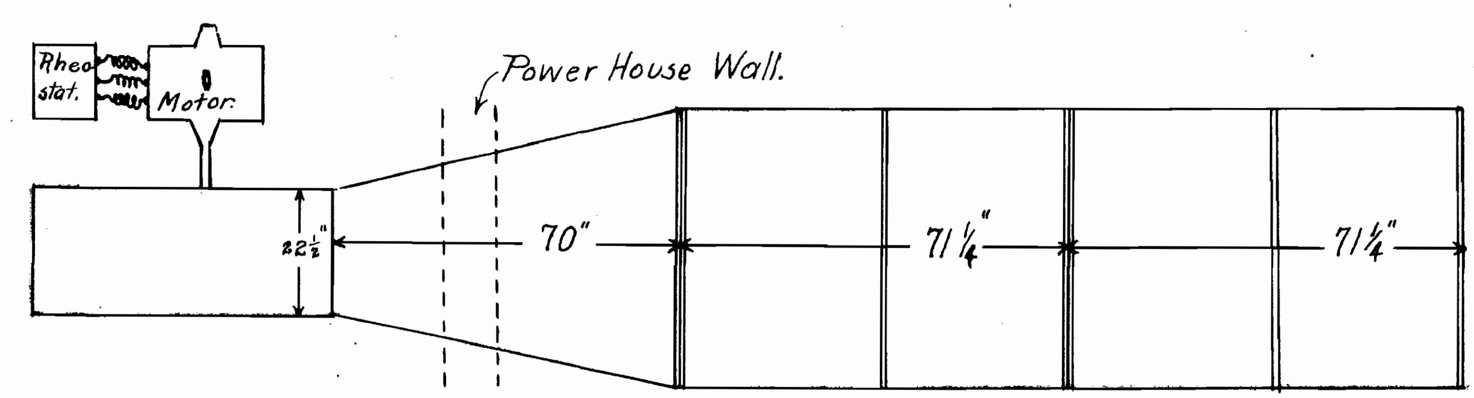
CHART No. 5
Showing the relation of constant Mechanical H.P., Air H.P., Speed and Velocity per second, when plotted against Quantity and pressure.
——— = Mechanical H.P.
------ = Air H.P.
——··· = Speed
——– – = Velocity per sec.
Quantity of Air discharged per second.
Cu.ft.
400
300
200
100
0
1"
2"
3"
4"
5"
6"
7"
Water gauge pressure.
40 H.P.
32 H.P.
24 H.P.
16 H.P.
10 Air H.P.
8 Air H.P.
6 Air H.P.
4 Air H.P.
140 V
120 V
100 V
80 V
720 R.P.M.
620 R.P.M.
520 R.P.M.
420 R.P.M.

Elevation – Fan and Tunnel.

Diagram No. 1.



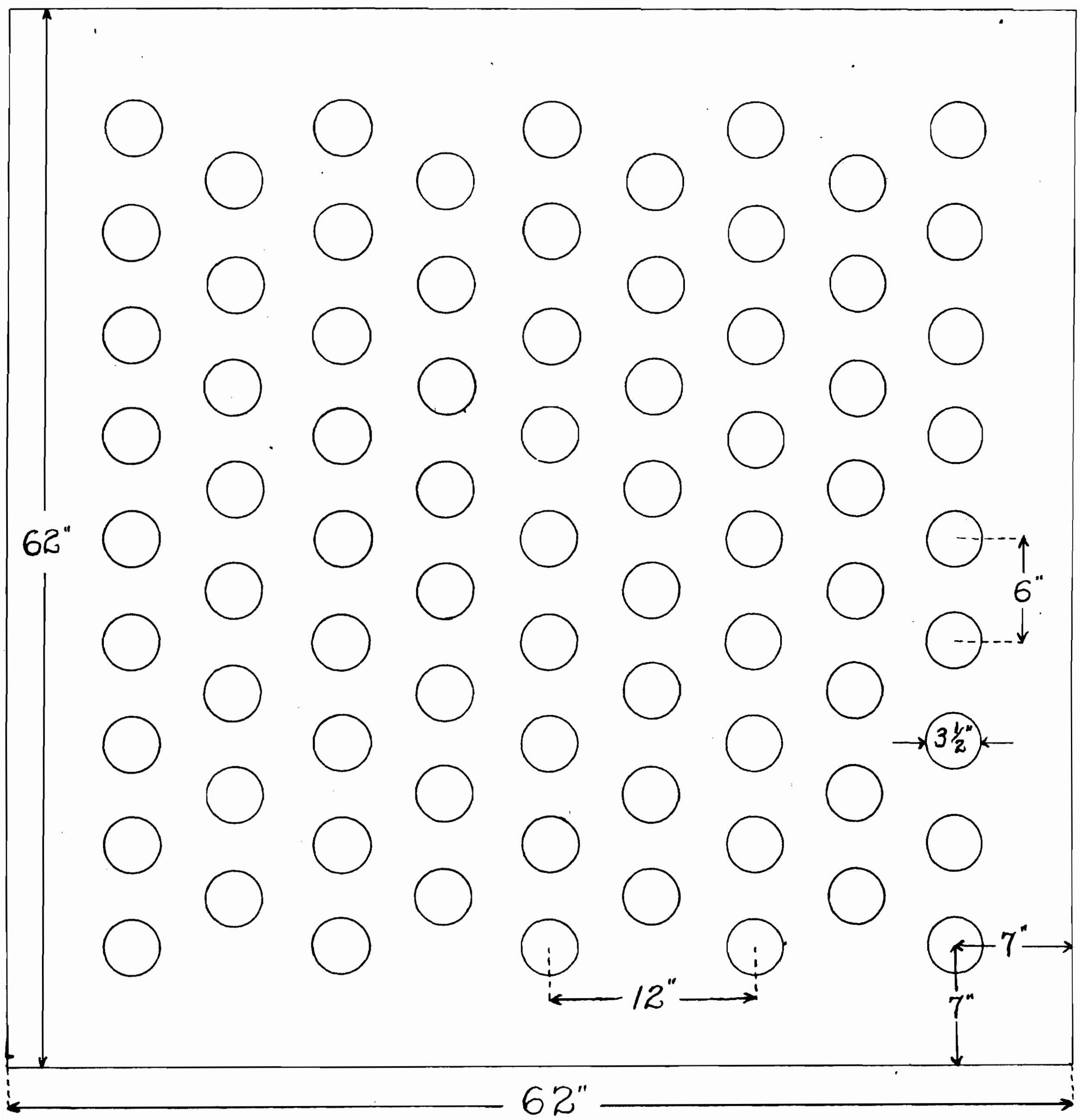

Plan – Fan and Tunnel.



View of 3½" Orifice.

77 Openings spaced as shown.

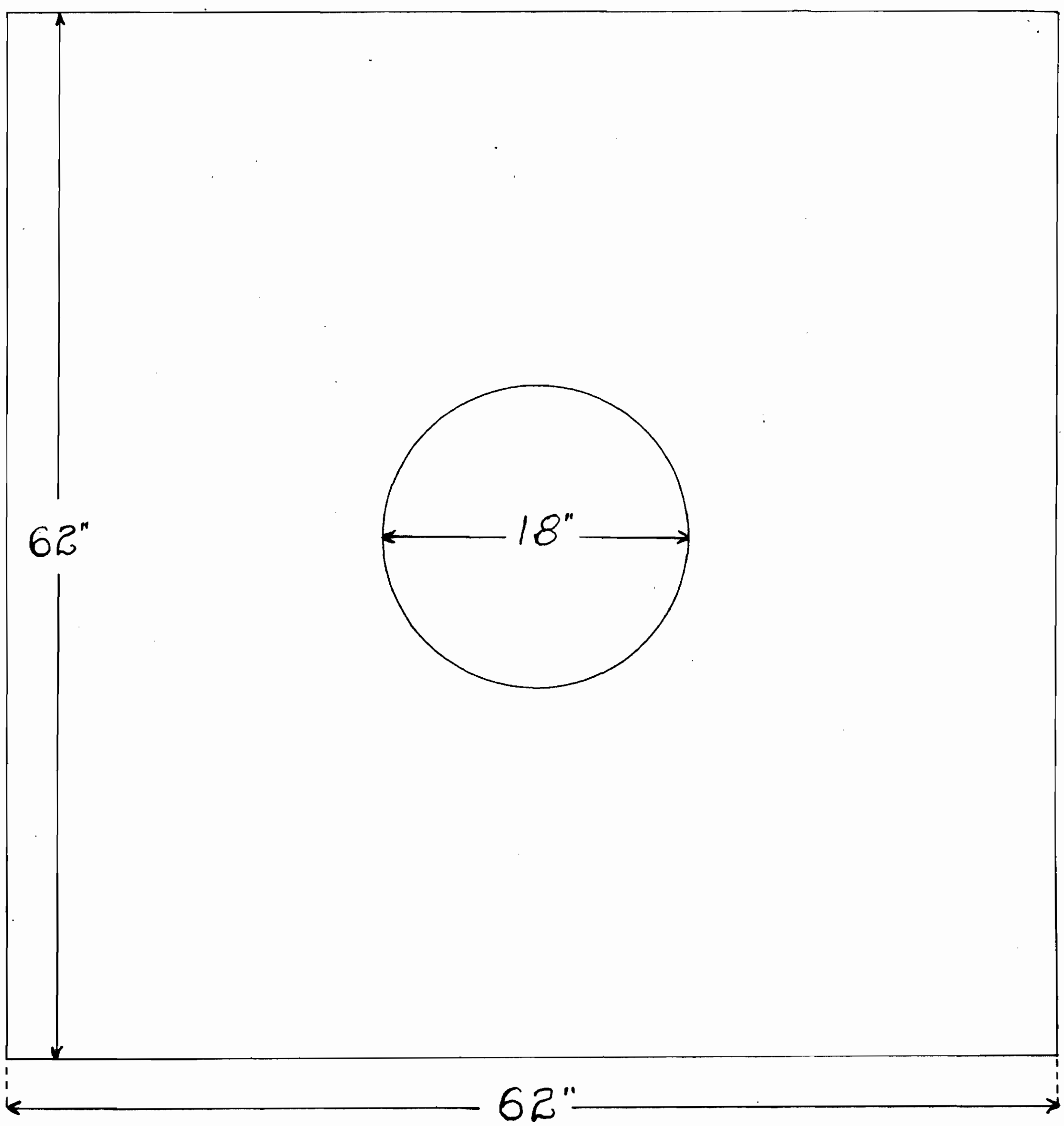
Diagram No. 2.




Scale:- 1/10 Actual Size.

View of 18" Orifice.

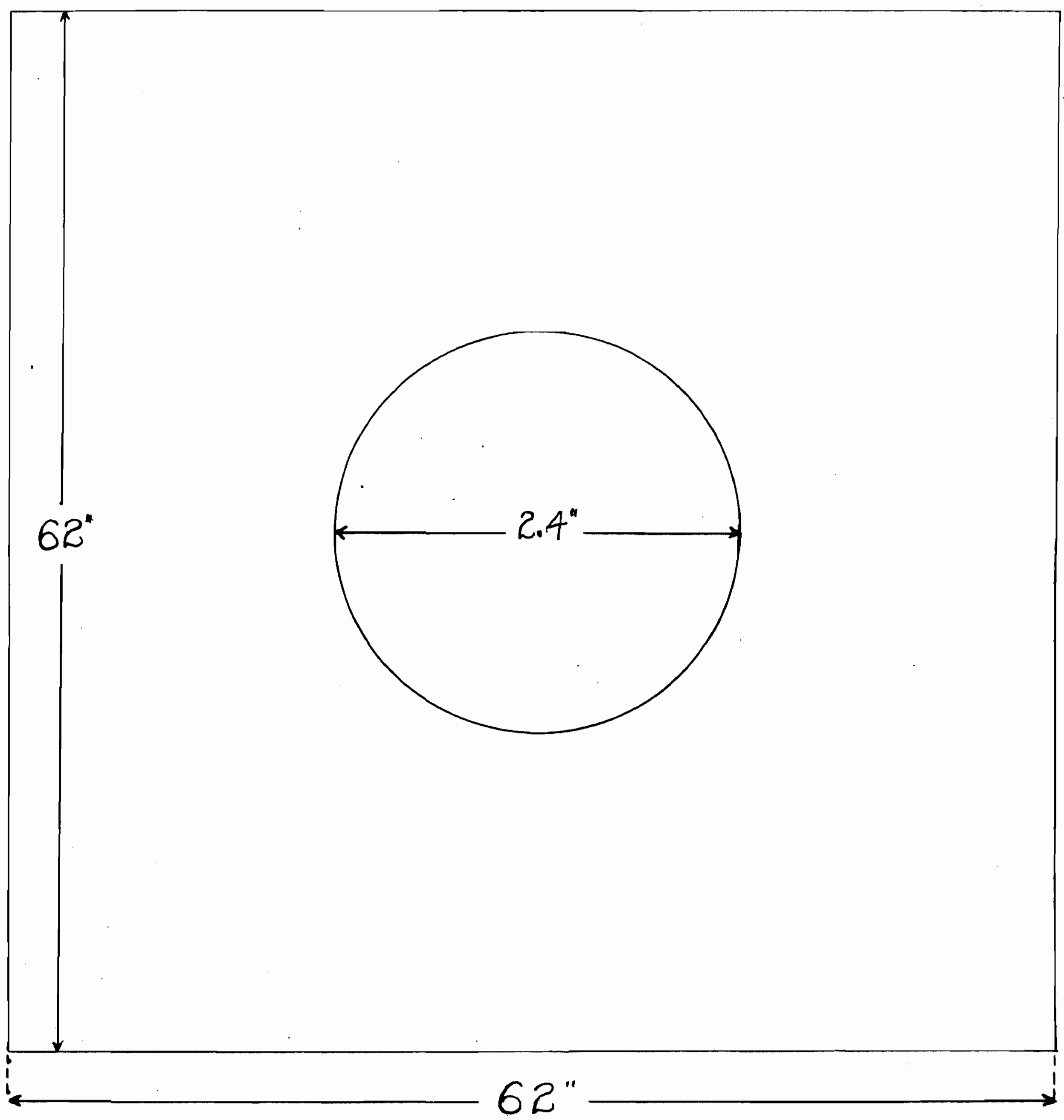
Diagram No. 3.




Scale:- 1/10 Actual Size.

View of 24" Orifice.

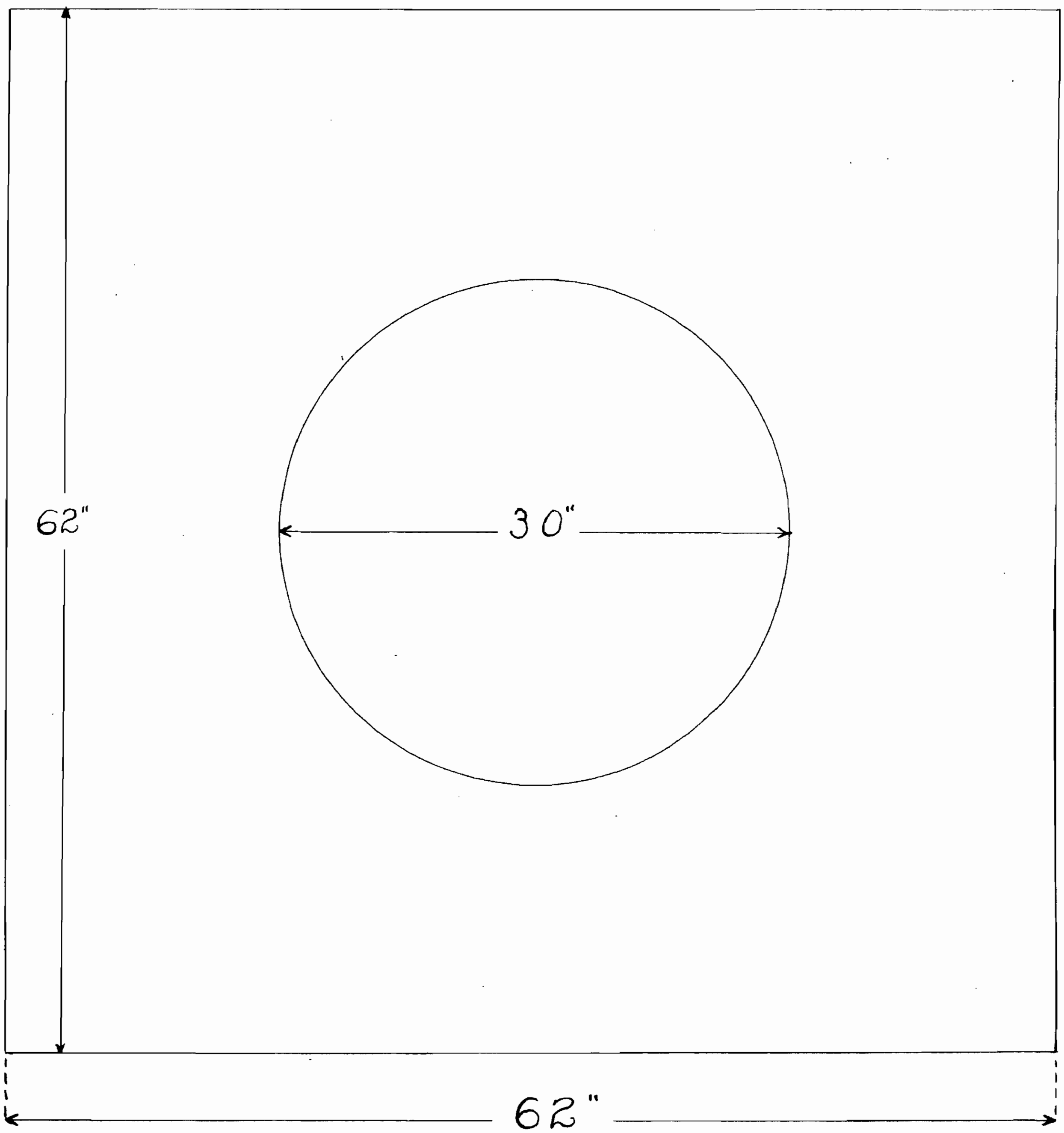
Diagram No. 4.



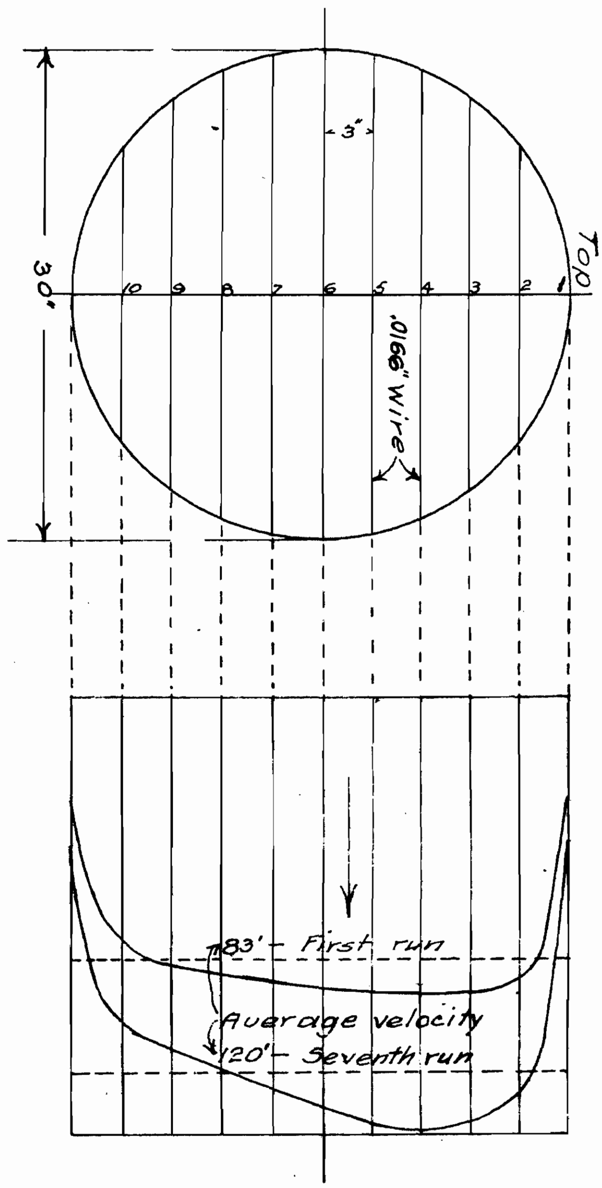

Scale:- 1/10 Actual Size.

View of 30" Orifice.

Diagram No. 5.

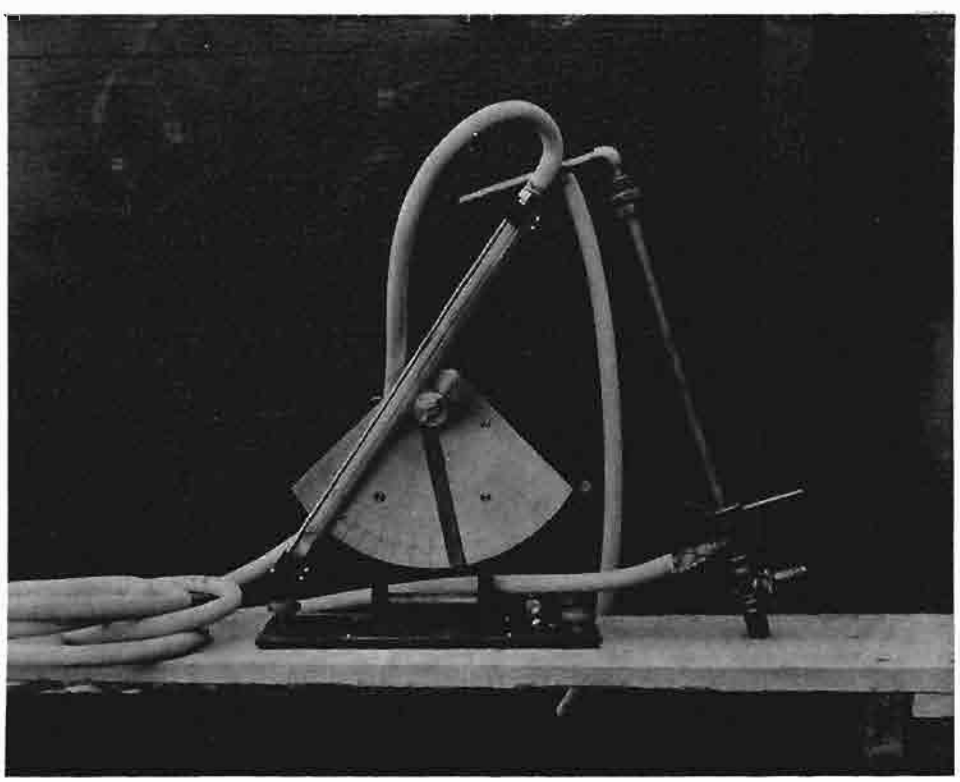



Scale:- 1/10 Actual Size.



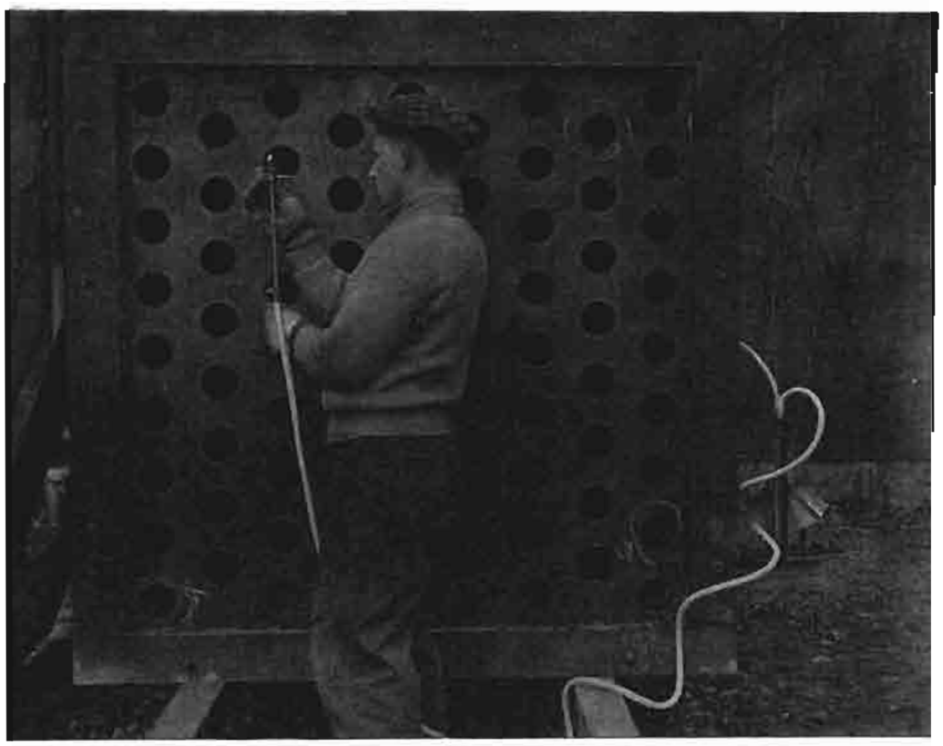

Drawing No. 6

Drawing No. 6 shows the spacing of wires in the 30 inch orifice for taking velocity readings and the velocity curve from top to bottom of orifice for the first and seventh runs.



Picture No. 1

*Picture No. 2*



Picture No.3

# B I B L I O G R A P H Y

A Sucessful Fan Test by J. T. Beard,

E. and M. J., Vol. 80, page 194.

Determining the efficiency of a Ventilating Fan,

M. and M., Vol. 21, page 194.

Economy of varying the speed of mine Ventilating Fans,

Coal age September 5th, 1914.

Experiments on two Guibal Fans by E. Brown,

T. F. I. M. E., Vol. 4, page 532.

Facts and Theories relating to Fans by D. M. Mowat Coll'y Guardian August 16th, 1912, and Coll'y Eng., March 1913.

Fan Tests by W. H. Booth Coll'y Engr., Vol. 11, page 185.

Low Pressure Fans by J. S. Leese, Power, March 19th, 1912.

Manometric Efficiency of Fans by G. m. Capell,

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Measurement of air in Fan work by C. H. Treat,

Engineering Review, October 15th, 1912.

Method of Testing a Fan, E. and M. J., Vol. 85, page 1013.

Mine Fan Tests, P. C. M. and M., Soc. S.A., Vol. 7, page 306.

Modern Ventilating Machines by W. Charlton,

Ir. and Coal Trades Review, June 21, 1912.

Notes on Fan gauges in connection with Fan Testing by

D. M. Capell, T. F. I. M. E., Vol. 3, page 196.

The Capell Fan M. and M., Vol. 18, page 316.

The Testing of Fans by R. Royd - book, 1911.

The Testing of Fans Ir. and Coal Tr. Rev., April 18th, 1913.

The Testing of Fans by T. Bryson,

Colliery Guardian August 14th, 1914.

Tests on a Mine Fan by J. B. Thompson,

T. I. M. E., Volume 32, page 295.

The Waddle Fan by S. C. Haigh,

Science and Art of Mining, September 14th, 1912.

# I N D E X