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An efficiency test of a laboratory fan

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AN EFFICIENCY TEST OF A LABORATORY FAN.

BY

DANIEL WEBSTER BLAYLOCK
EDWARD ALBRECHT SCHROER
ELTON ARTHUR MILLER

A

THESIS

submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
in partial fulfillment of the work required for the
DEGREE OF
BACHELOR OF SCIENCE IN MINE ENGINEERING

Rolla, Mo.
1915

Approved by

Clued Harris
Professor of Civil Engineering

18504

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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_v = Amperes.

C = Coefficient of discharge.

C_p = 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_e = Equivalent orifice.

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

d = Inside diameter of fan.

d_w = 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. $= \frac{\pi d(\text{RPM})}{60}$
 $= .157(\text{RPM})$

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 ^{through} in orifice.

v_1 = Velocity of air ^{through} in 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 Gauge $i_r = \frac{P_s^2 w}{g P_w}$

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

(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

$$v = \sqrt{2gh} \quad h = \frac{(i_s + i_x)d}{12 w}$$

$$\text{then } v = \sqrt{\frac{2gd(i_s + i_x)}{12 w}} = \sqrt{\frac{2 \times 32.2 \times 62.5(i_s + i_x)}{12 w}}$$

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

(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.

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

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

$W = 0.6184 d^2 \sqrt{\frac{i_s}{T}}$ as developed by R. J. Durley, page

197, vol. 27, A.S.M.E. $W = .6184 \text{ cnd}^2 \sqrt{\frac{i_s}{T}}$

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

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

8. Volumetric Capacity of fan = $\frac{\pi}{4} (D^2 - d^2) \frac{b}{60} (\text{RPM})$
 = $\frac{\pi b}{240} (D^2 - d^2) (\text{RPM})$ 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.

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

$$P_w \approx 5.2 \quad W = W A v \quad \text{H.P.} = \left(\frac{Q i_s + \frac{W A v^3}{35,420}}{105.8} \right)$$

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"

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

15. Pitot Tube coefficient C. Is the actual velocity of the air flowing thru the orifice per second divided by the velocity as measured by the Pitot Tube.

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

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.

M E A S U R I N G A P P A R A T U S

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.

EXPERIMENTS

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 $3\frac{1}{2}$ in., 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 upon 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 apparatus

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 $3\frac{1}{2}$ in. 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 ^cincreased from the top of the orifice down to points No. 3_A ^{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 $3\frac{1}{2}$ in., 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 $3\frac{1}{2}$ in., 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 $3\frac{1}{2}$ in. and 18in., 24in., and 30in., orifices. as calculated by formula No. 6, using Durley's Coefficient of discharge for the $3\frac{1}{2}$ in.

Columns No. 10 and 11 show the coefficients of discharge for the $3\frac{1}{2}$ in., 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 capacity 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 $3\frac{1}{2}$ in., 18in., 24in., and 30in. orifices. The coefficient for the $3\frac{1}{2}$ inch orifice was determined by Professor R. J. Durley of McGill 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 $3\frac{1}{2}$ inch 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 30 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 0.73

Exp	RPM	Volts	Amp	Bar	Inside - Ther'		Orifice- i_s	
					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	0.55	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.

Exp	RPM	Volts	Amp	Bar	Inside - Ther'		Orifice- i_s	
					Dry	Wet	$3\frac{1}{2}$ in.	24in.
1	494	235	53	29.01	87.5	70.0	0.90	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' Orifice- i_s			
					Dry	Wet	$3\frac{1}{2}$ in.	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
No.	$(i_s + i_x)$	Velocities	Q - $3\frac{1}{2}$ in.	Q - 18in.	Disch' - C					
	$3\frac{1}{2}$	18	$3\frac{1}{2}$	18	The'l Act'l	The'l Act'l	The'l Act'l	The'l Act'l	$3\frac{1}{2}$	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	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	i_s	i_t	i_{so}	i_v
	Temp.				
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	i_s	i_t	i_{50}	i_v
	Temp.				
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	83	67.5

No.	Outside	i_s	i_t	i_{so}	i_v
	Temp.				
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	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	i_s	i_t	i_{so}	i_v
	Temp.				
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'	Equip Orif'	C_v	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

3½ 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	115.5	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'	Equip' Orif'	C _v	C _d	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_r	i_s	i_t	i_r	$\frac{i_s}{i_r}$	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'	Equip' 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	v	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 $4\frac{1}{2}$ inches diameter as determined by Professor R. J. Durley at McGill University, and the 18in., 24in., and 30 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
$5/16$ in.	0.603	0.606	0.610	0.613	0.613
$1/2$ in.	0.602	0.605	0.608	0.610	0.613
1 in.	0.601	0.603	0.605	0.606	0.607
$1\ 1/2$ in.	0.601	0.601	0.602	0.603	0.603
2 in.	0.600	0.600	0.600	0.600	0.600
$2\ 1/2$ in.	0.599	0.599	0.599	0.598	0.598
3 in.	0.599	0.598	0.597	0.596	0.596
$3\ 1/2$ in.	0.599	0.597	0.596	0.595	0.594
4 in.	0.598	0.597	0.595	0.594	0.593
$4\ 1/2$ in.	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

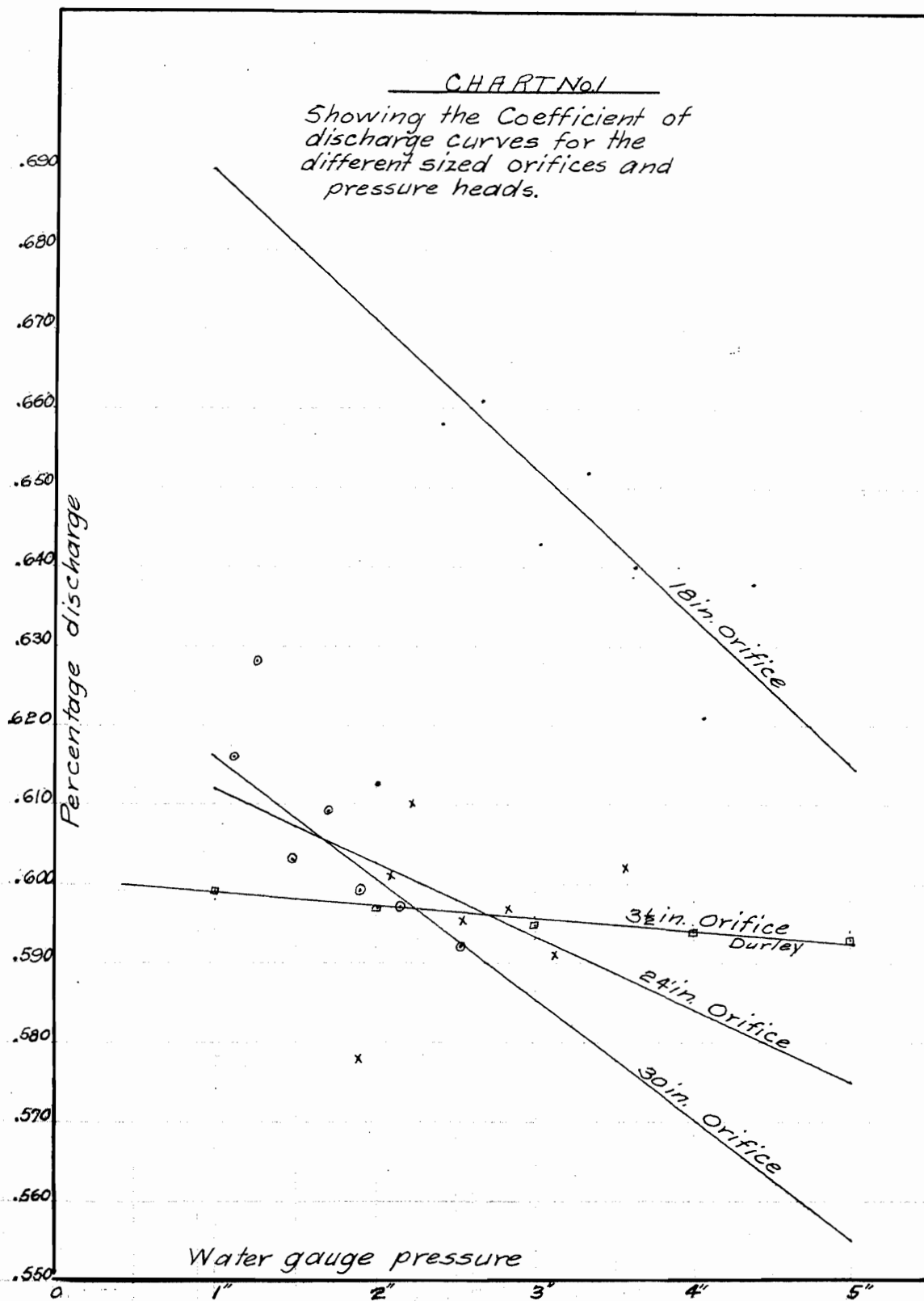


CHART No 2

Showing the relation of horsepower, quantity and pressure for the different sized orifices

— = H. P. — pressure curves
 - - - = Quantity - " - "

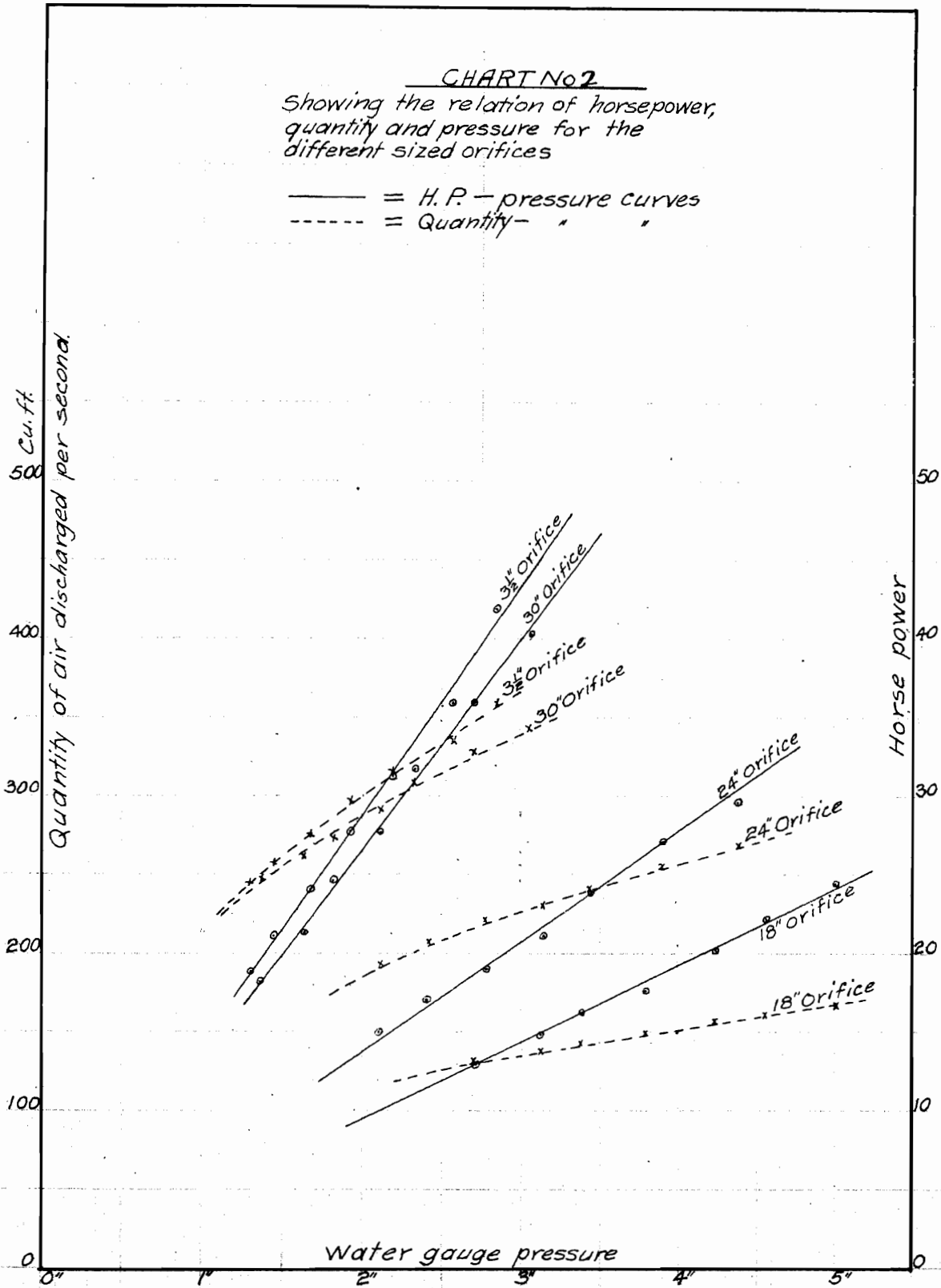


CHART No. 3

Showing relation of Speed, Air Horsepower and pressure for different sized orifices.

— = Air horsepower-pressure curves
 - - - = Speed - pressure curves

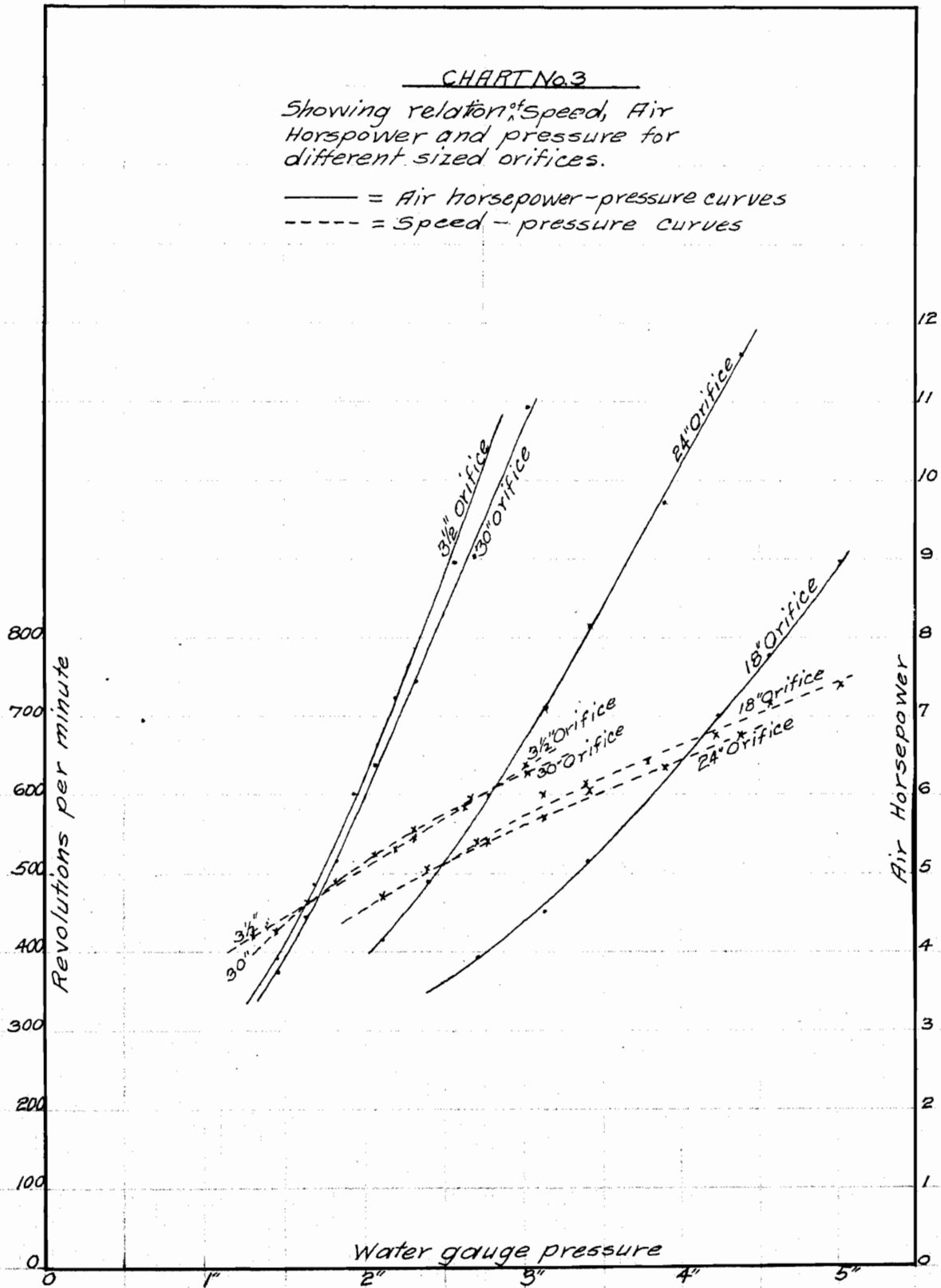


CHART No. 4

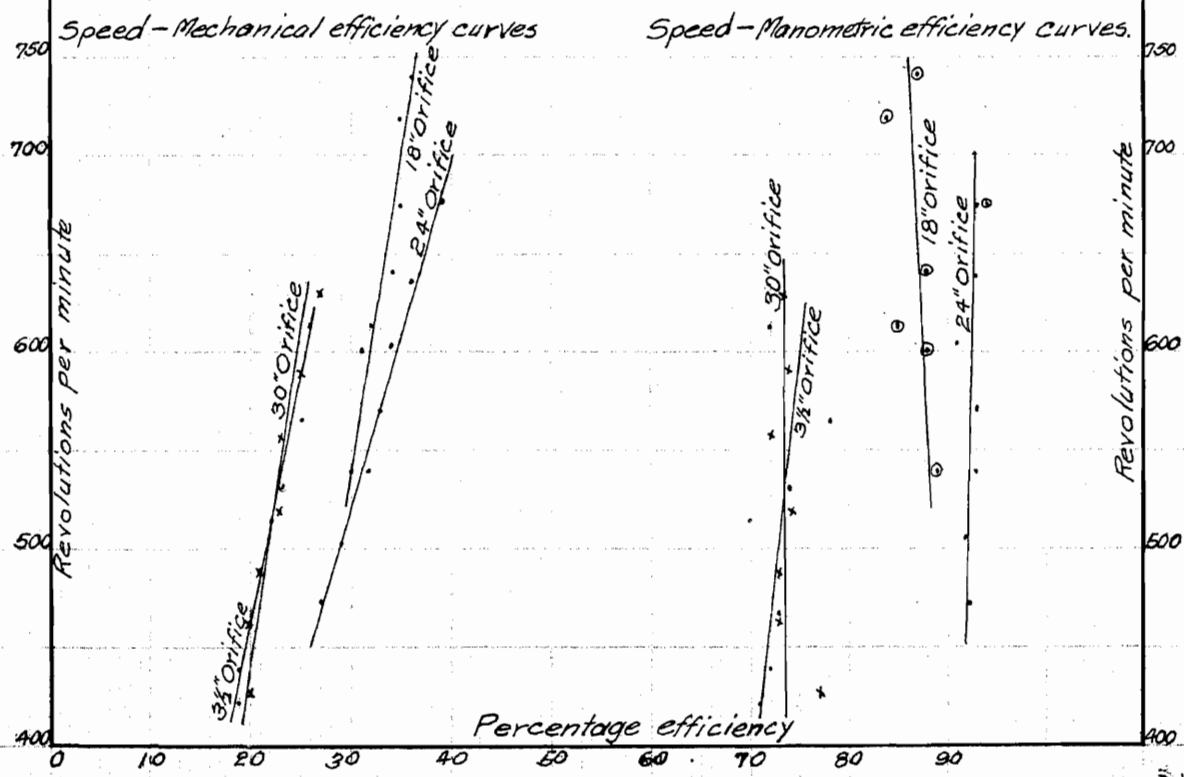
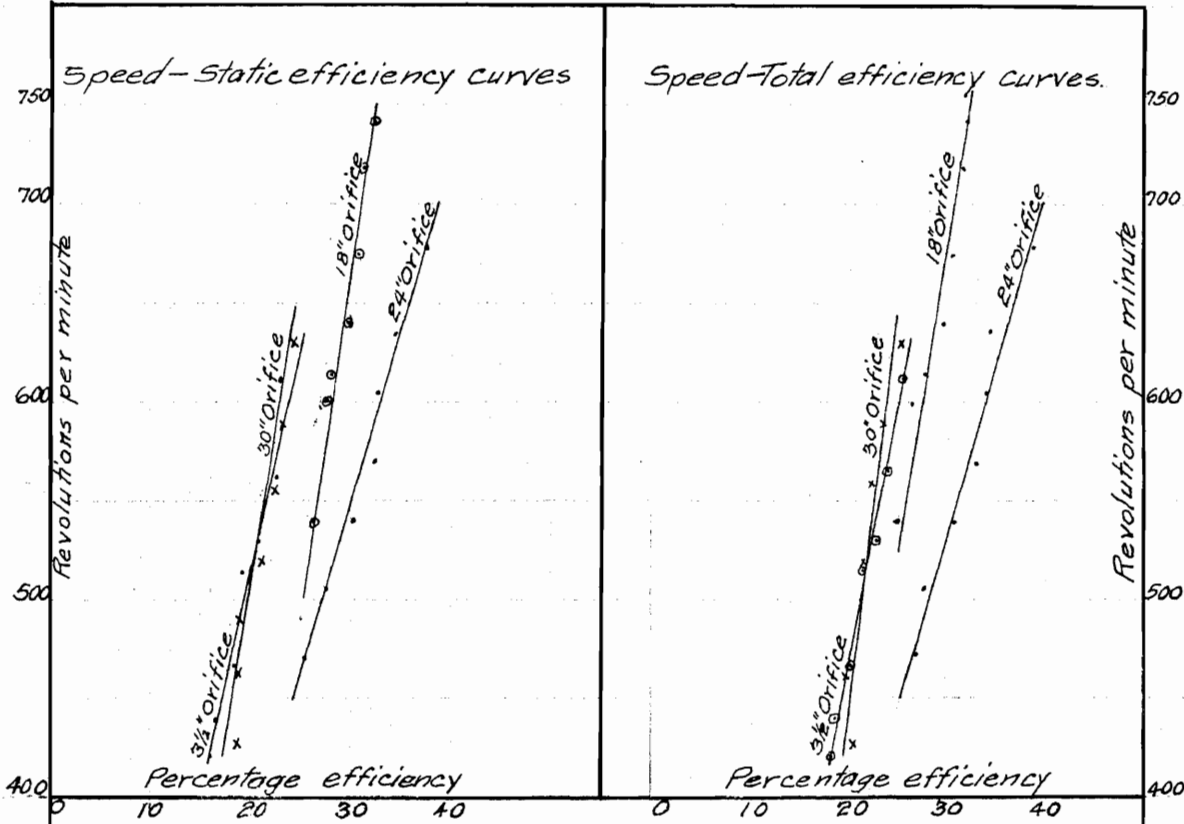


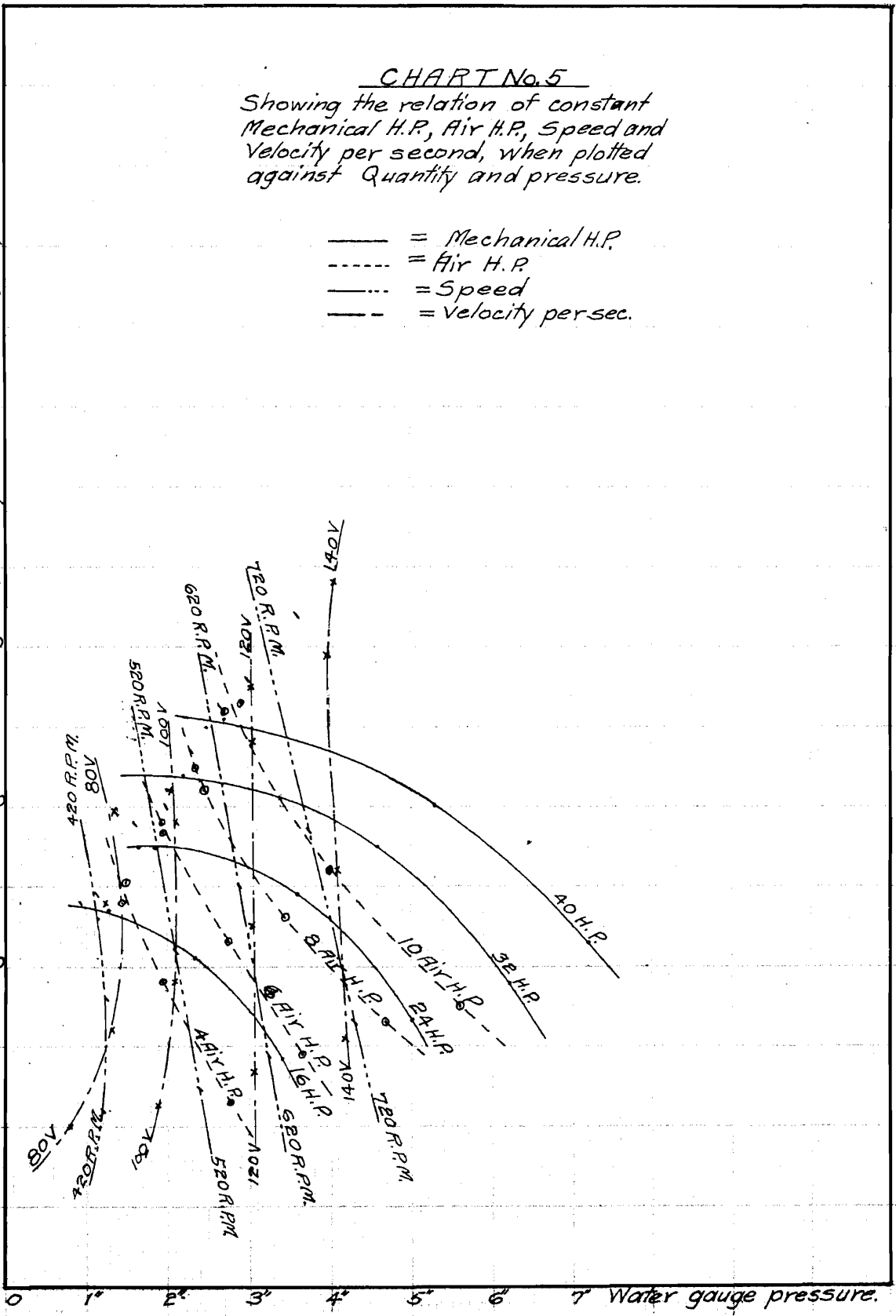
CHART No. 5

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



Water gauge pressure.

Elevation - Fan and Tunnel.

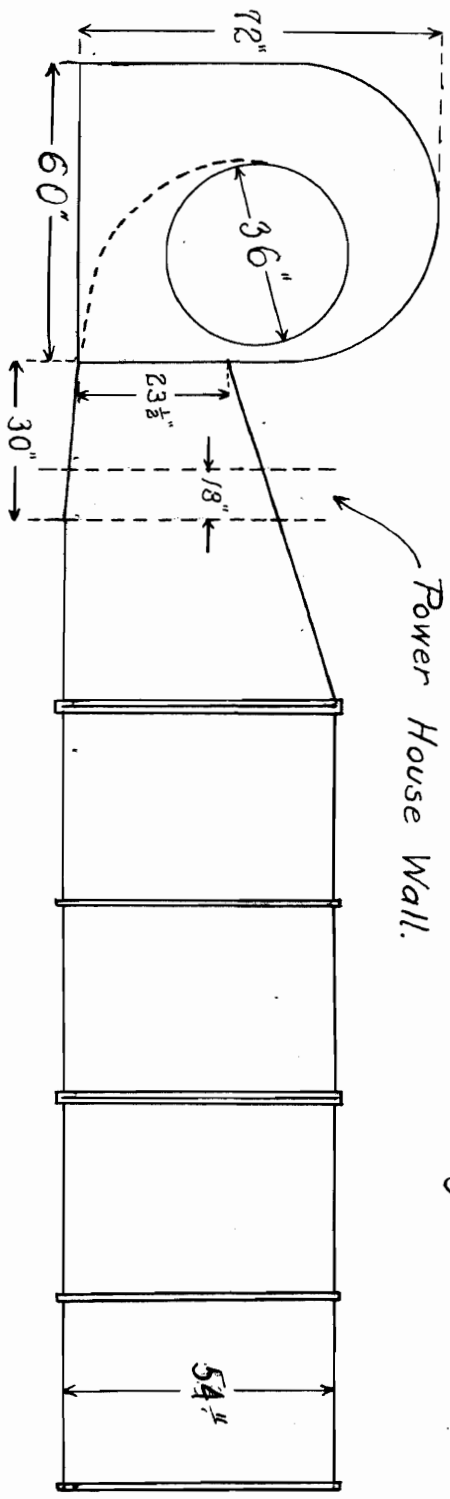
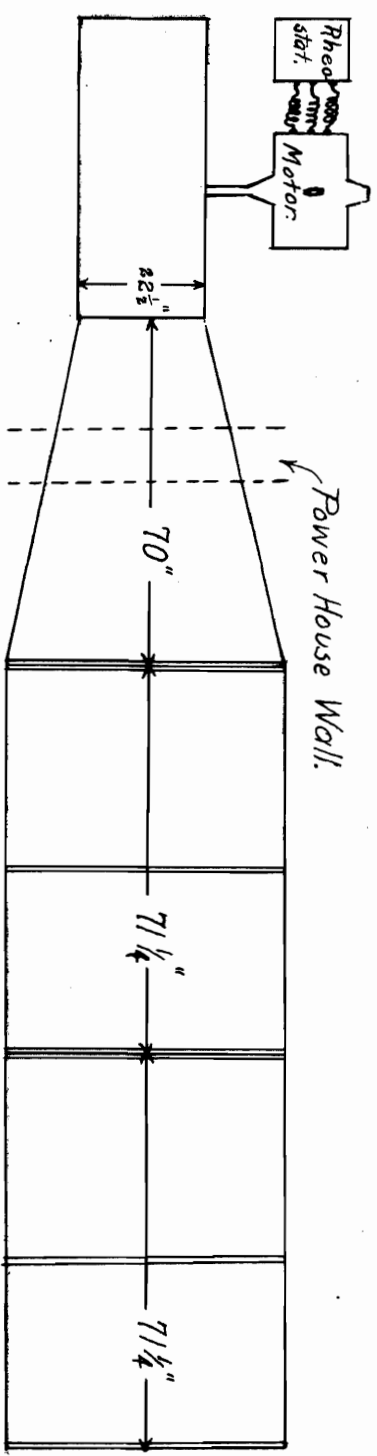


Diagram No. 1.

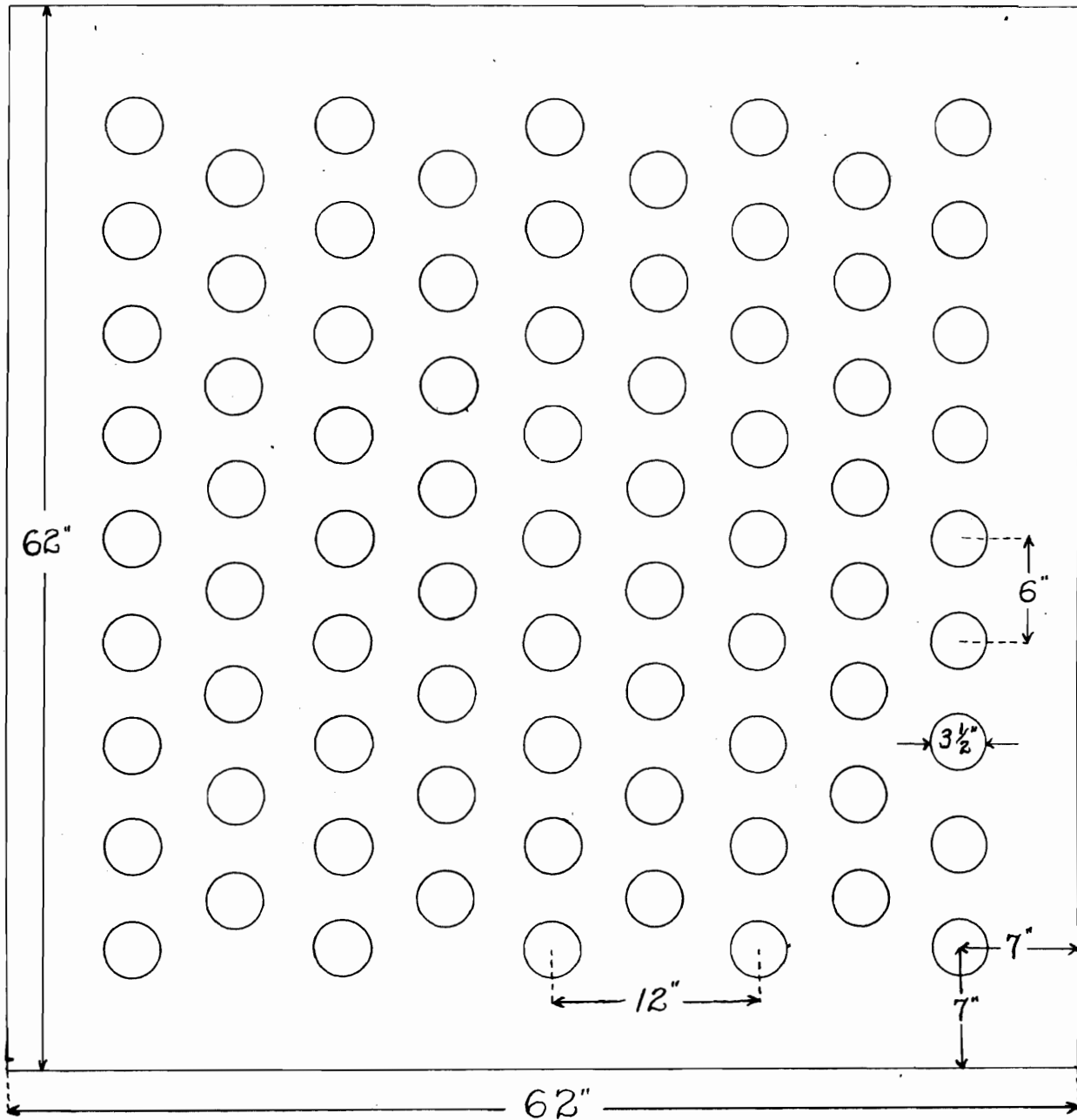
Plan - Fan and Tunnel.



View of $3\frac{1}{2}$ " Orifice.

77 Openings spaced as shown.

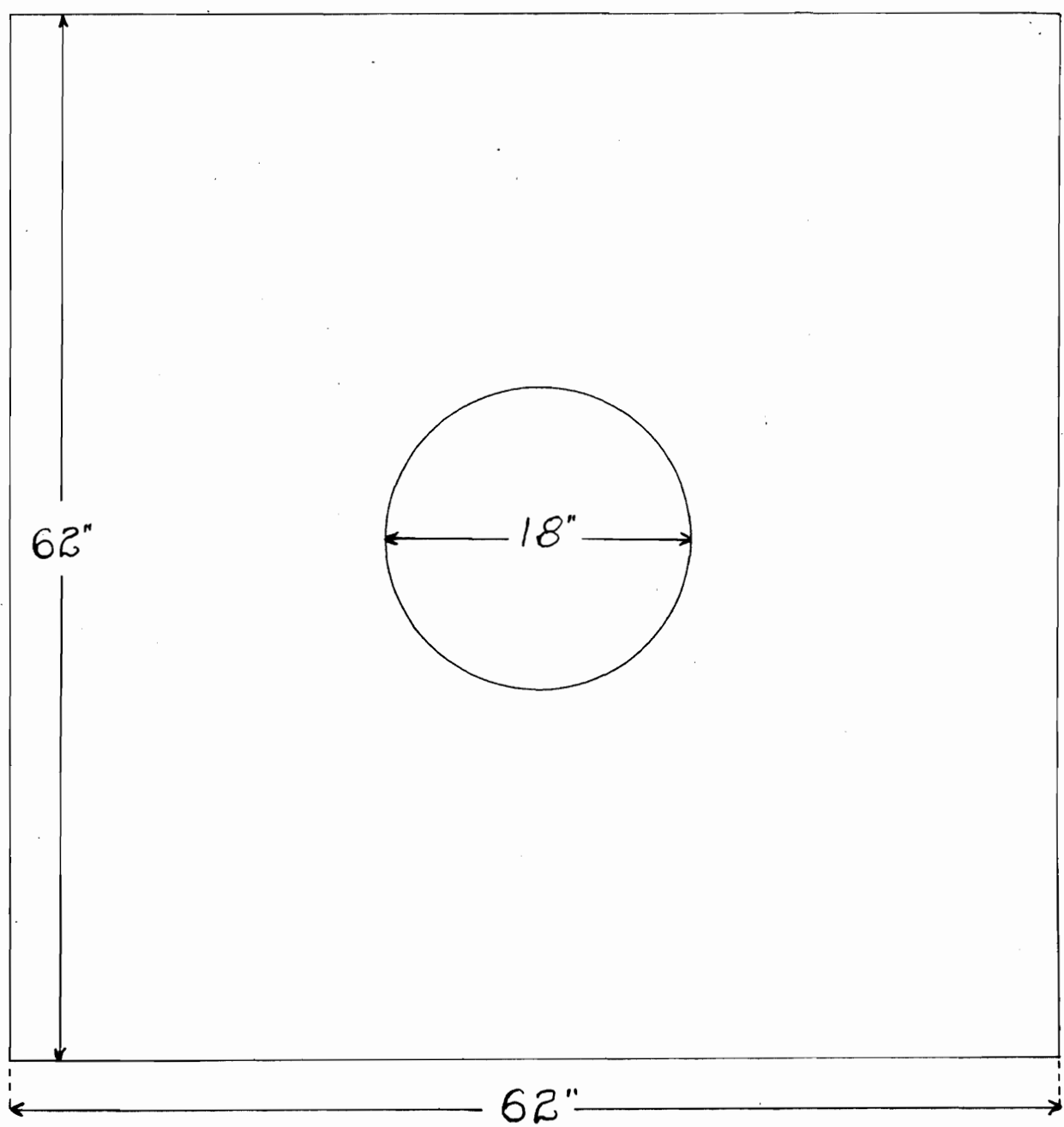
Diagram No. 2.



Scale: $\frac{1}{10}$ Actual Size.

View of 18" Orifice.

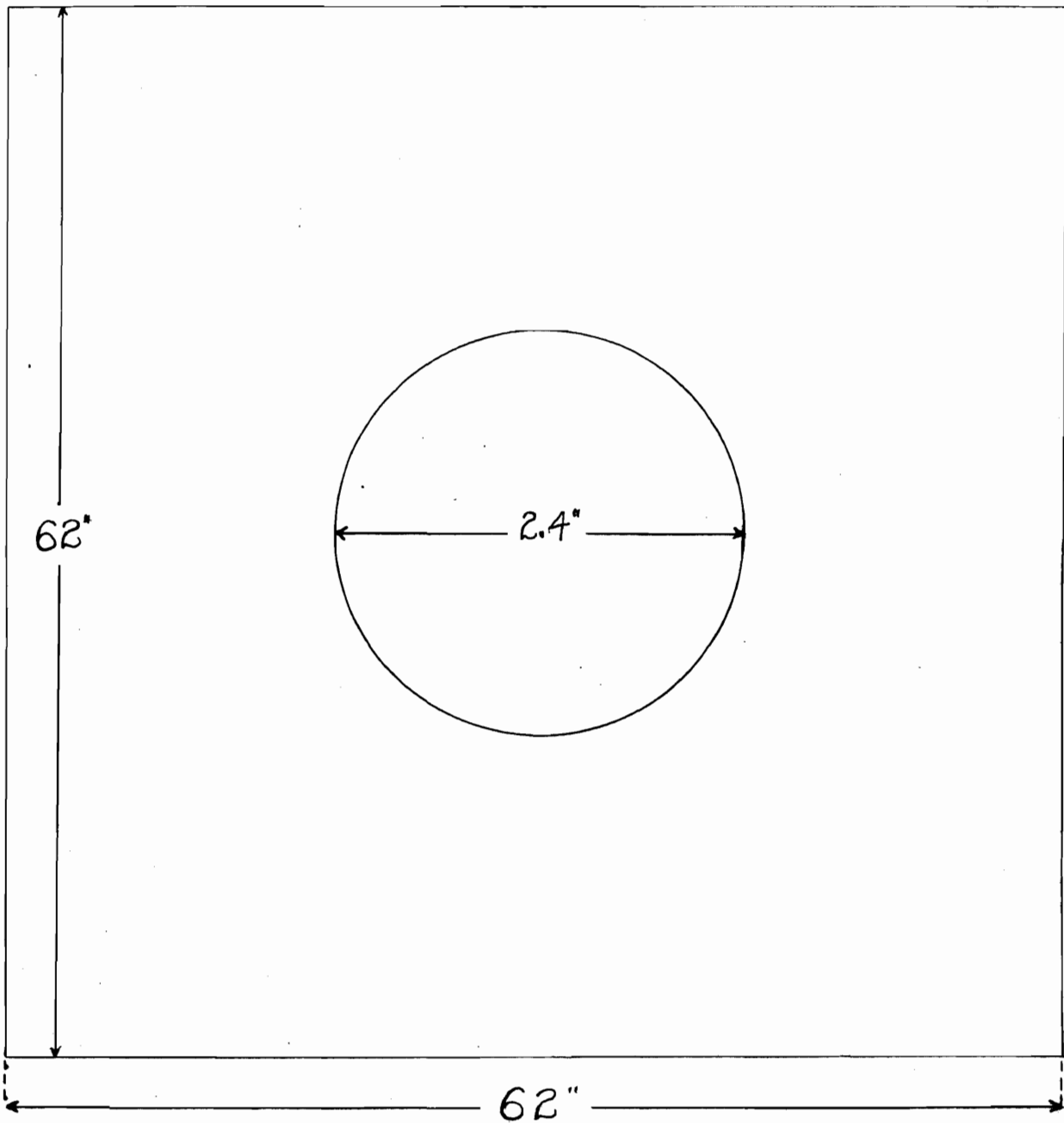
Diagram No. 3.



Scale:- $\frac{1}{10}$ Actual Size.

View of 2.4" Orifice.

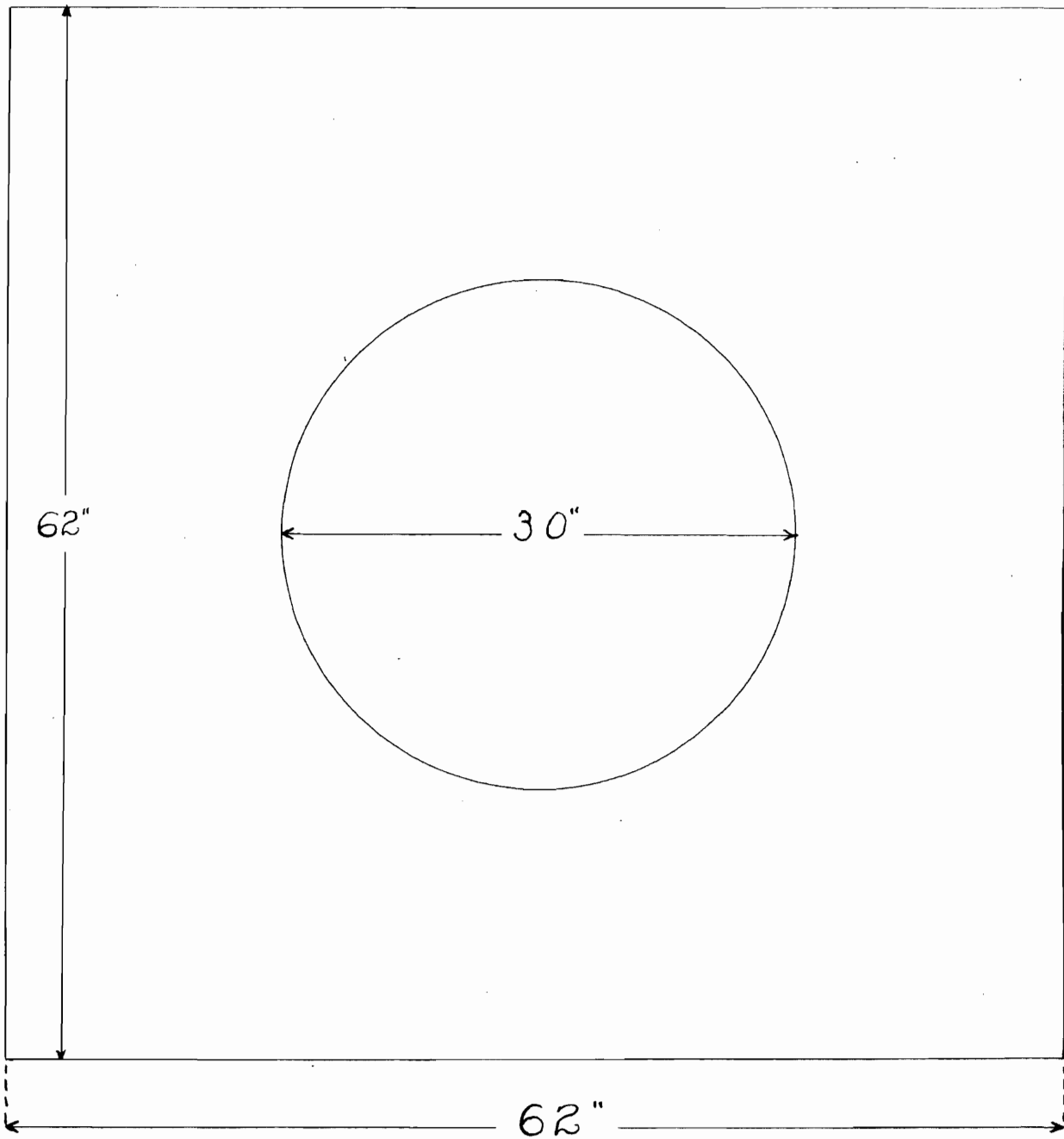
Diagram No. 4.



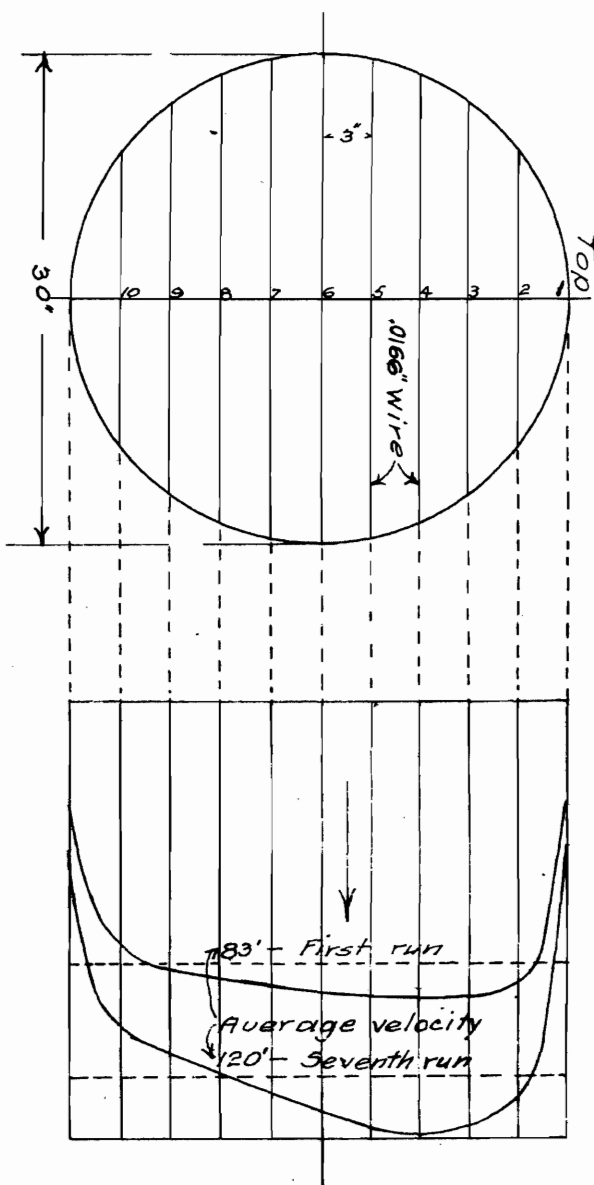
Scale:- $\frac{1}{4}$ Actual Size.

View of 30" Orifice.

Diagram No. 5.

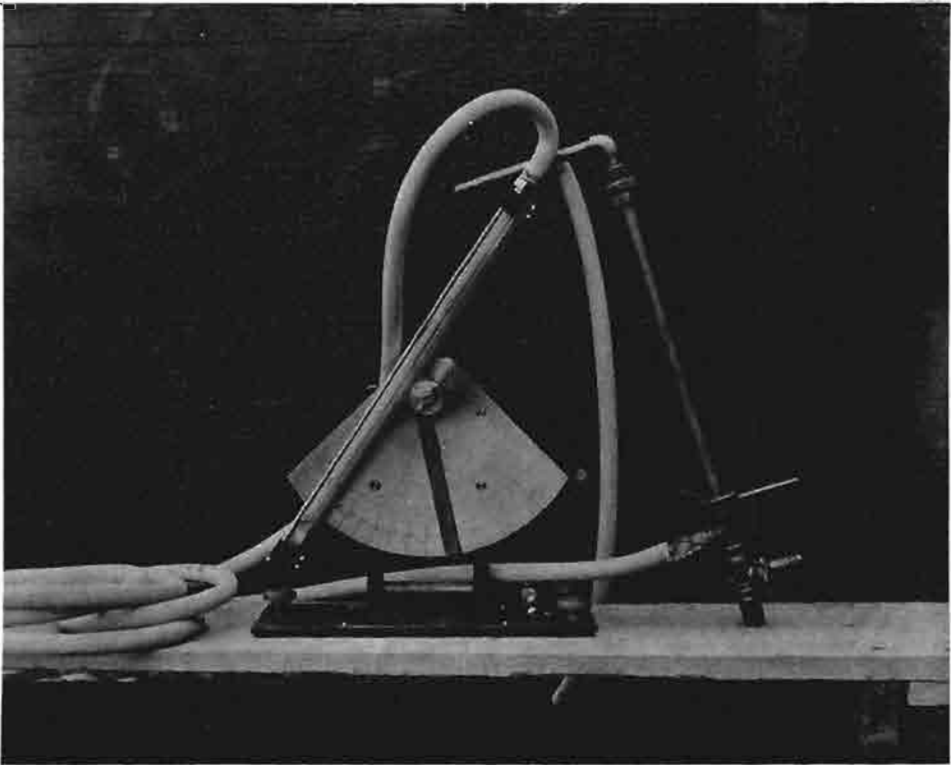


Scale:- $\frac{1}{4}$ Actual Size.



Drawing No. 6

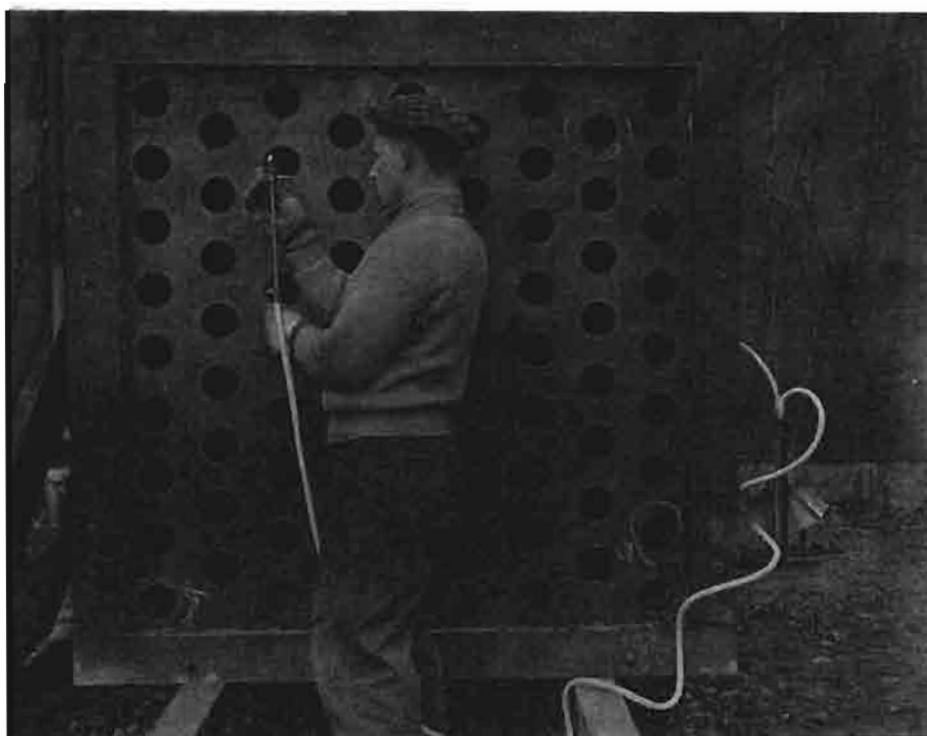
Drawing No. 6 shows the spacing of wires in the 30 inch orifice for taking velocity readings and the velocity curve from top to bottom of orifice for the first and seventh runs.



Picture No. 1



Picture No.2



Picture No.3

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