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Friction of air in small pipes and fittings

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FRICTION OF AIR IN SMALL PIPES AND FITTINGS.

by

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A

T H E S I S

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LIST OF ILLUSTRATIONS.

FRICTION OF AIR IN SMALL PIPES AND FITTINGS.

The work of Park and Peterson during 1909-10 at the Missouri School of Mines revealed the fact that more data are needed concerning the loss of pressure due to elbows and other fittings of pipes under three inches in size. Accordingly, we decided to undertake the continuation of their work as a thesis.

The apparatus used was practically the same as used in the previous thesis and was as follows:

One single stage air compressor of 77 cu.ft. per min. free air capacity and pressure up to 100 pounds, gage at 110 revolutions per minute.

One two stage compressor of 100 cu.ft. free air capacity and pressure up to 150 pounds gage at 110 revolutions per minute.

One air receiver of about three cu.ft. capacity.

One drum especially constructed for measuring air by orifice according to the method originated by Prof. Dudley at McGill University and published in "Compressed Air" Vol.II, 1906-07, pp.4181. This drum is supplied

with orifices cut in copper plates about 3/32 inch in thickness and ranging from 1/2 inch to 3-1/2 inches in diameter.

All pipes and fittings used were new, the pipes being galvanized and the fittings were cast iron. The pipe sizes were 1/2, 3/4, 1, 1-1/2, and 2 inches.

The fittings for each size of pipe:

Ordinary 90° elbows.

Long sweep 90° "

45° "

Return bends (open and closed pattern)

Globe valves

A number of 12 inch nipples.

The pressure gages used were corrected by a gage tester.

The differential gage was the one constructed expressly for this work by Holmes and Wander of class 1910.

For a more detailed description see the thesis by these gentlemen.

The indicating fluids used were mercury for the small pipe up to 1-1/2 inches and for the 1-1/2 and 2 inch, water. The plan of the assembled apparatus

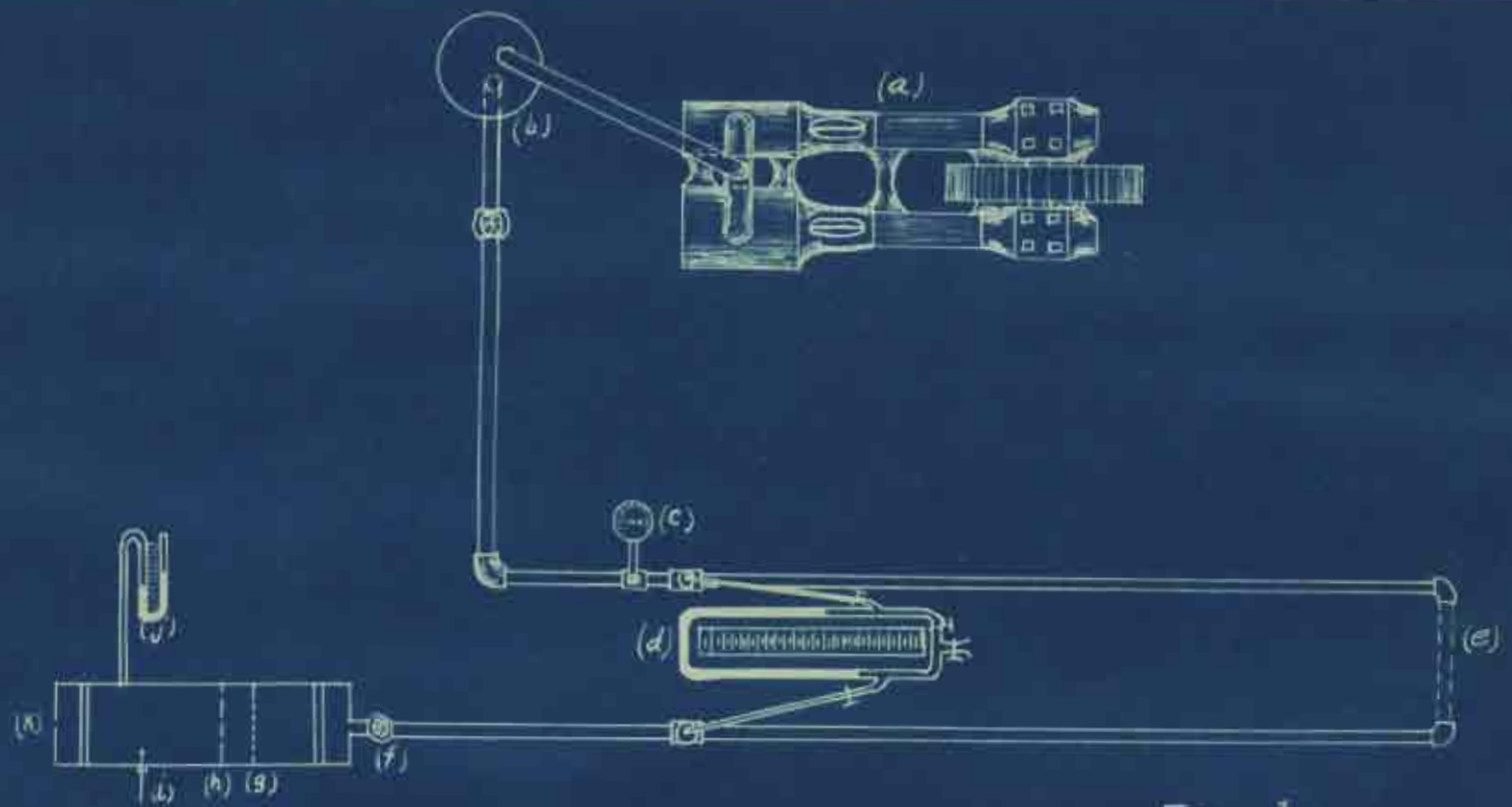

Fig. 1.

Allen + Cody.

is shown in Fig.1. The explanation of the lettering of which is shown below.

a = compressor of larger capacity. (small compressor was used comparatively little and was connected in parallel with the larger).

b = receiver of 3 cu.ft. capacity.

c = pressure gage showing initial pressure in air pipes.

d = differential gage.

e = point at which fittings were connected in the line.

f = throttle valve for controlling pressure in the line.

g = screen in orifice drum.

h = baffle board in orifice drum.

i = position of thermometer.

j = "U" gage for measuring pressure in drum.

k = position of orifice in drum.

The gages "c", "d", and "j" are shown in a horizontal position for the purpose of better illustration. The photograph on page 24 will also aid in giving a clearer idea as to apparatus.

METHOD OF PROCEEDURE IN TAKING DATA.

By varying the speed of the compressors the free air volume "Va" was controlled. While the compressor was running at a uniform speed the pressure in the system was controlled by the throttle valve "f".

The orifice was varied to keep the pressure in the drum within the limits of 2 inches and 6 inches, which range was covered by Dudley in his experiments.

Each size of pipe required, on the average, seven runs. Eighteen readings were taken on each run. This makes a total of about 35 sets of readings.

Data for each run was taken as follows:

Reading on differential gage or "z" of tables.

Reading on "U" gage --- "i" of tables.

Initial pressure in pipe---"P_2" of tables.

Temperature in drum --- "Tc" of tables

Diameter and length of pipe, also number and kind of fitting.

Diameter of orifice ---"Do'" of tables.

The pressure range in each run on pipes less than 2 inches in diameter was from 0 pounds to 150 pounds gage, or about twelve atmospheres.

FORMULAE USED IN COMPUTATIONS.

The friction formula, $f = c.\frac{l}{d5}\ \frac{Va^2}{r}$, was taken from "Harris' Compressed Air Computations". Notation as follows:

f = loss of pressure in pounds per sq.in.

l = length of pipe in feet.

Va = volume of free air passing in cu.ft. per sec.

d = diameter of pipe in inches.

r = ratio of compression in atmospheres.

c = experimental coefficient covering all constants.

The free air volume (Va) was determined by the use of the orifice drum of Dudley's experiments and in the calculations of which two formulae were used which were also taken from "Harris' Compressed Air Computations".

$$\text{Weight of air passing} = Q = K\ C.1632\ d^2\sqrt{\frac{1}{t}}\ Pa.$$

$$\text{The free air volume} = Va = \frac{Q}{Wa}$$

Va = free air volume in cu.ft per second.

Wa = weight of 1 cu.ft. of free air = .073. pound approximately at Rolla.

Q = weight of air passing the orifice in pounds per second.

d = diameter of orifice in inches.

i = difference in level of water columns in "U" gage in inches.

t = absolute temperature (Fahr.) of air in orifice drum.

Pa = absolute pressure of atmosphere in pounds per square inch = 14.2 pounds approximately at Rolla.

k = experimental coefficient determined by Dudley.

The "f" in the friction formula was computed in the following manner from the readings on the differential gage.

$f = \left(\frac{62.5 \times 13.6}{1728}\right) z$, where "z"=difference in height of the mercury columns in inches. When water was the indicating fluid used, the above formula becomes,

$f = \left(\frac{62.5}{1728}\right) z'$, where z' = difference in height of the water columns in inches.

The "r" of the friction formula was the average in the pipe and was calculated as follows:

$$r = \frac{P - 1/2\ f + Pa}{Pa}$$

P = gage pressure at entrance.

The meaning of the various symbols used in the tables is shown below.

z = differential gage reading in inches of mercury or water.

f = loss of pressure in pipe in pounds per square inch.

P_2 = gage reading at entrance.

r_2 = ratio of compresion in terms of atmospheres.

r_m = average ratio of compression in pipe.

i = "U" gage reading in inches of water.

Tc = temperature in drum in degrees. Centigrade (Converted during calculation to absolute degrees Fahr.)

Do = diameter of orifice

$\frac{Va^2}{rm}$ = (self explanatory)

S = velocity of air in pipe in feet per second.

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f' = "f" subjected to a correction for pipe temperature made thus:

$$f' = f \frac{t_a b}{t_2} = f \frac{t_a}{t_2}$$

f' corrected friction

f = original friction

t_a = absolute room temperature

t_2 = pipe temperature.

During the eighteen readings on each run, readings were taken on a thermometer strapped to the pipe midway on its length.

These readings averaged for six different pressures:

P_2	t_a
20	535
50	536
75	542
100	548
125	554
150	560

An effort was made at first to keep the length of pipe constant but as the only advantage of this was the saving of a little algebra (with the expenditure of much muscular effort and the waste of pipe) this was soon abandoned.

In the formula $f = C. \frac{l}{d_5} \frac{Va^2}{r,}$ with "l" and "d" constant, if "c" is also constant, then "f" and $\frac{Va^2}{r}$ will plot to a straight line. This we find to be the case to a very reassuring degree, as is evidenced in plates 1 to 6.

The object of these experiments was to find the value "c" in the friction formula and coefficients for loss in the various fittings.

In tables "A","B" and "C" will be found under the heading "Loss of Pressure" a coefficient which, multiplied by $\frac{Va^2}{r}$ will give loss, by friction, in pounds per sq. inch for one fitting as indicated.

In table "D" will be found the coefficient "C" of the formula

$$f = c \frac{l}{d_5} \frac{Va^2}{r}$$

This "c" is found as follows:

When l = I the above formula becomes

$$f = \frac{l}{d_5} \frac{Va^2}{r}$$

Now from results worked out from plates and equations we have the values for "f" for one foot of pipe.

Thus for 1 inch pipe $f = .070 \frac{Va^2}{r}$

Whence $.070 \frac{Va^2}{r} = c. \frac{1}{(1.07)^5} \frac{Va^2}{r}$

$c = .070 (1.07)^5$

$c = .099$

Lack of time prevented the calculation for the 1/2 and 3/4 inch pipe and these were omitted from this thesis.

Equations containing the number and kind of fittings and total loss of pressure due to these fittings were made up. All these equations gotten from one size of pipe were solved as simultaneous equations, thus obtaining the constant ~~K~~ Coefficient for each kind of fitting. These are shown as multiplied by $\frac{Va^2}{r}$ in the column, "Loss of Pressure".

By dividing the "loss of "pressure" due to each fitting by loss of pressure due to one foot of pipe we obtained the equivalent length of pipe in feet, to these fittings. These results are tabulated in the column, "Equivalent length of pipe in feet".

The effect of unreamed ends proved to be of importance so this was included in our investigation. The results of this are also shown in tables "A", "B", and "C". The effect of reamed ends was found to be practically negligable. This fact enabled us to make the calculation of results on the 1-1/2 inch pipe which owing to one run being incorrect (due probably to some obstacle in the pipe) would otherwise have had to be omitted or re-run.

It will be seen that tables "A", "B", and "C" give valuable conclusions as to the friction due to various fittings in terms of feet of straight pipe.

In calculating $\frac{"Va2"}{r}$ and "S", of the tables, logrithms were used as much as possible. This simplified the work considerably after the scheme was systematized.

The nominal diameters of the pipes were found to be slightly less than the actual diameter; the actual diameters of the pipes were used in the calculations.

Table of nominal and actual diameters of pipes.

	Size of pipe in inches.				
Diameter	Nominal	1/2	3/4	1	1-1/2	2
	Actual	.64	.82	1.07	1.63	2.08

Table 1. Actual diameter of pipe = 1.07". Length pipe = 80'
Fittings: 2-elbows, 13 nipples (unreamed ends)

No.	z" (Hg)	f	P_2	r_2	r_m	i	Tc	d_o" (Orifice)	$\frac{V_a^2}{r_m}$	S	f' (Corrected)
1	50.9(H_2O)	1.82	22	2.58	2.56	1.9	13.0	1.50	.186	45	1.83
2	7.0	3.44	24	2.74	2.62	4.2	14.0	"	.403	65	3.44
3	9.7	4.77	25	2.79	2.62	5.8	13.0	"	.560	76	4.77
4	1.3	0.64	52	4.69	4.67	1.4	13.0	"	.072	17	0.62
5	3.5	1.22	50	4.58	4.54	3.4	13.0	"	.124	28	1.18
6	5.7	2.86	51	4.64	4.54	4.8	13.0	"	.264	39	2.75
7	2.3	1.13	75	6.33	6.30	3.4	13.5	"	.134	24	1.05
8	1.5	0.74	75	6.33	6.31	2.0	13.5	"	.079	19	0.69
9	4.3	2.11	75	6.33	6.26	5.9	14.0	"	.240	32	1.96
10	0.8	0.39	100	8.09	8.08	1.3	15.0	"	.040	12	0.35
11	1.9	0.93	100	8.09	8.07	3.2	15.0	"	.099	18	0.84
12	3.3	1.62	100	8.09	8.04	5.5	15.0	"	.135	24	1.45
13	0.7	0.34	125	9.86	9.84	1.3	16.0	"	.021	8	0.30
14	1.8	0.85	125	9.86	9.83	3.5	16.0	"	.083	15	0.75
15	2.3	1.13	124	9.80	9.76	6.5	17.0	"	.165	21	0.98
16	0.8	0.39	150	11.64	11.63	1.3	18.0	"	.028	8	0.33
17	1.4	0.69	150	11.64	11.61	3.0	18.0	"	.032	9	0.58
18	2.9	1.43	150	11.64	11.61	6.6	18.5	"	.140	18	1.30

TABLE 2. Actual diameter of pipe = 1.07". Length pipe = 80'
Fittings: 2-elbows, 13 nipples (reamed ends).

No	z" (Hg)	f	P_2	r_2	r_m	i	Tc	d_o"	$\frac{V_a^2}{r_m}$	S	f'
1	2.1	1.03	20	2.42	2.40	1.5	11.0	1.50	.157	43	1.03
2	5.6	2.73	20	2.42	2.32	4.0	10.0	"	.432	72	2.73
3	10.5	5.18	20	2.42	2.24	7.8	11.0	"	.881	102	5.18
4	1.8	0.86	50	4.53	4.53	2.5	11.0	"	.125	27	0.85
5	3.3	1.62	50	4.55	4.50	4.6	11.0	"	.256	40	1.56
6	5.6	2.75	50	4.55	4.46	7.5	11.0	"	.424	51	2.65
7	0.9	0.42	75	6.32	6.30	1.6	12.0	"	.069	18	0.39
8	2.5	1.20	75	6.32	6.28	3.7	12.5	"	.145	25	1.12
9	3.3	1.59	75	6.32	6.27	5.4	12.5	"	.215	30	1.48
10	0.9	0.44	100	8.09	8.07	1.7	14.0	"	.051	13	0.39
11	2.1	1.03	100	8.09	8.06	4.2	14.0	"	.131	21	0.93
12	3.8	1.87	100	8.09	8.03	7.8	15.0	"	.243	29	1.67
13	0.4	0.10	125	9.86	9.85	0.9	15.0	"	.021	4	0.09
14	1.3	0.64	125	9.86	9.84	3.2	16.0	"	.051	12	0.55
15	2.7	1.33	125	9.86	9.82	7.2	16.5	"	.181	22	1.15
16	0.8	0.37	150	11.64	11.63	1.6	17.0	"	.033	9	0.31
17	1.5	0.74	150	11.64	11.62	4.0	18.0	"	.085	14	0.62
18	2.3	1.11	150	11.64	11.60	6.5	19.0	"	.133	18	0.93

TABLE 3. Actual diameter of pipe = 1.07" Length pipe = 80'
Fittings: 2-elbows, 1-nipple (ureamed ends).

No.	Z" (Hg.)	f	R_2	r_2	r_m	i	T_c	d_o"	$\frac{V_a^2}{r_m}$	S	f' Corrected
1	8.1	3.99	18	2.24	2.10	1.6	17.0	2.0	0.603	89	4.04
2	17.7	8.70	22	2.54	2.23	3.8	17.0	"	1.291	126	8.80
3	9.4	4.63	38	3.67	3.51	3.0	18.0	"	0.674	73	4.70
4	13.6	6.70	41	3.88	3.69	4.7	19.0	"	1.014	87	6.64
5	3.1	1.53	35	3.46	3.41	1.1	20.5	"	0.252	40	1.52
6	2.3	1.13	18	2.24	2.20	0.5	20.5	"	0.178	37	1.12
7	1.9	0.94	70	5.94	5.91	1.1	21.0	"	0.145	23	0.89
8	4.8	2.12	70	5.94	5.86	2.9	21.5	"	0.319	39	2.02
9	8.1	3.99	68	5.80	5.66	4.2	21.5	"	0.579	52	3.80
10	7.5	3.70	100	8.05	7.92	2.1	21.0	"	0.207	27	3.40
11	4.9	2.42	99	7.95	7.87	3.4	21.0	"	0.338	34	2.23
12	6.8	3.35	102	8.19	8.07	4.8	21.0	"	0.464	40	3.08
13	1.5	0.74	125	9.85	9.81	1.1	22.0	"	0.087	16	0.66
14	4.6	2.27	122	9.65	9.57	3.0	22.0	"	0.244	27	2.02
15	5.1	2.52	120	9.50	9.42	4.1	22.0	"	0.339	32	2.24
16	1.3	0.64	153	11.85	11.83	1.1	22.5	"	0.072	13	0.55
17	2.9	1.43	150	11.60	11.55	3.2	23.0	"	0.215	22	1.23
18	3.0	1.48	150	11.60	11.55	4.0	23.0	"	0.269	25	1.28

TABLE 4. Actual diameter of pipe = 1.07" Length pipe = 80'.
Fittings: 10-elbows, 9 nipples (unreamed ends)

No.	Z" (Hg.)	f	R_2	r_2	r_m	i	T_c	d_o"	$\frac{V_a^2}{r_m}$	S	f'
1	4.6	2.26	22	2.56	2.48	1.9	12.0	1.50	0.197	47	2.25
2	7.8	3.85	24	2.70	2.56	3.34	12.0	"	0.321	59	3.81
3	14.3	7.05	24	2.70	2.35	5.9	12.0	"	0.618	108	7.00
4	5.2	2.57	50	4.54	4.45	4.3	12.0	"	0.236	38	2.45
5	2.0	0.99	50	4.54	4.50	1.5	12.0	"	0.079	22	0.94
6	10.0	4.92	51	4.60	4.42	7.5	12.5	"	0.418	51	4.70
7	1.7	0.84	75	6.31	6.28	1.9	13.0	"	0.071	17	0.77
8	4.2	2.07	75	6.31	6.24	4.4	13.0	"	0.175	28	1.90
9	7.2	3.55	75	6.31	6.19	7.2	14.0	"	0.287	36	3.25
10	2.1	1.04	100	8.08	8.05	2.5	14.0	"	0.075	16	0.95
11	3.2	1.58	100	8.08	8.03	4.3	15.0	"	0.131	21	1.38
12	5.5	2.71	100	8.08	7.98	7.0	15.0	"	0.209	27	2.31
13	1.3	0.64	125	9.85	9.83	2.2	15.0	"	0.053	12	0.57
14	2.0	0.98	125	9.85	9.82	2.9	16.0	"	0.089	14	0.84
15	5.2	2.56	125	9.85	9.76	8.0	16.0	"	0.201	24	2.20
16	1.2	0.59	150	11.65	10.63	2.0	17.0	"	0.029	9	0.49
17	2.0	0.99	150	11.65	10.62	3.9	17.5	"	0.090	15	0.82
18	4.7	2.32	150	11.65	10.57	8.6	17.5	"	0.198	22	1.92

TABLE 5. Actual diameter of pipe = 1.07" Length pipe = 80'.
Fittings: 4 globe valves, 2 elbows, 5 nipples (unreamed ends)

No.	Z" (Hg)	f	P_2	r_2	r_m	l	T_c	d_o" (Orifice)	$\frac{V_o^2}{r_m}$	S	f' (Corrected)
1	7.2	3.55	21	2.49	2.36	1.8	10.0	1.50	0.189	47	3.52
2	20.2	10.00	20	2.42	2.07	9.3	10.0	"	0.492	71	9.90
3	31.2	15.90	24	2.70	2.15	7.3	9.0	"	0.852	107	15.24
4	2.1	1.20	45	4.20	4.16	0.9	9.0	"	0.053	19	1.07
5	11.0	5.41	45	4.20	4.01	4.4	9.5	"	0.218	43	5.20
6	20.2	10.00	46	4.26	3.91	8.3	9.5	"	0.529	61	9.60
7	3.2	1.58	72	6.10	6.05	2.1	10.5	"	0.035	12	1.48
8	7.2	3.55	70	5.96	5.84	4.3	11.0	"	0.183	29	5.32
9	13.9	6.88	70	5.96	5.13	7.9	12.0	"	0.342	40	6.40
10	1.8	0.89	100	8.09	8.07	1.6	13.0	"	0.049	13	0.81
11	5.2	2.55	100	8.09	8.00	4.3	14.0	"	0.131	21	2.32
12	9.5	4.67	100	8.09	7.93	7.5	14.0	"	0.233	23	4.25
13	2.0	0.98	124	9.80	9.77	1.7	16.0	"	0.093	14	0.87
14	5.4	2.66	125	9.86	9.77	4.9	16.0	"	0.077	18	2.36
15	7.8	3.84	124	9.80	9.67	7.0	16.0	"	0.171	22	3.40
16	2.1	1.04	150	11.64	11.61	2.2	17.0	"	0.045	10	0.90
17	3.8	1.88	150	11.64	11.58	4.4	18.0	"	0.092	15	1.62
18	7.0	3.45	150	11.64	11.53	7.8	18.0	"	0.164	16	2.99

TABLE 6. Actual diameter of pipe = 1.07" Length pipe = 80'.
Fittings: 6 return bends (open pattern), 2 elbows, 7 nipples (reamed ends).

No.	Z"	f	P_2	r_2	r_m	l	T_c	d_o"	$\frac{V_o^2}{r_m}$	S	f'
1	1.3	0.64	20	2.42	2.42	0.8	13.5	1.5	0.771	119	0.64
2	3.5	1.72	20	2.42	2.36	3.0	13.5	"	0.316	152	1.72
3	8.6	4.25	20	2.42	2.27	5.9	13.5	"	0.389	173	4.25
4	1.8	0.86	50	4.55	4.53	2.2	13.5	"	0.108	68	0.84
5	2.8	1.40	50	4.55	4.52	3.5	14.0	"	0.193	86	1.35
6	5.3	2.51	50	4.55	4.46	5.8	14.0	"	0.372	113	2.45
7	0.8	0.35	75	6.30	6.29	1.2	14.0	"	0.047	36	0.33
8	2.9	1.43	75	6.30	6.25	5.0	14.5	"	0.200	73	1.34
9	4.7	2.32	75	6.30	6.22	7.2	15.0	"	0.289	88	2.16
10	0.7	0.35	100	8.08	8.07	1.3	15.5	"	0.023	22	0.31
11	3.0	1.48	100	8.08	8.03	6.0	12.5	"	0.183	·	1.33
12	3.2	1.58	100	8.08	8.02	6.3	19.0	"	0.191	65	1.42
13	0.9	0.47	125	9.85	9.83	2.1	20.0	"	0.052	30	0.40
14	2.0	0.99	125	9.85	9.82	4.4	20.0	"	0.108	44	0.85
15	2.9	1.43	125	9.85	9.80	6.5	21.0	"	0.161	54	1.25
16	0.6	0.30	150	11.65	11.64	1.3	21.5	"	0.027	20	0.25
17	1.7	0.82	150	11.65	11.60	4.6	21.5	"	0.097	38	0.69
18	2.4	1.18	150	11.65	11.56	6.2	21.5	"	0.128	44	0.99

TABLE 7. Actual diameter of pipe = 1.63" Length pipe = 81.8'
Fittings: 2 elbows, 1 nipple (reamed ends).

No.	z" (H_2O)	f	P_1	r_1	r_m	i	T_c	d_o" (orifice)	$\frac{V_o"}{r_m}$	S	f' (corrected)
1	8.3	0.30	20	2.40	2.40	2.1	18.0	1.75	0.399	2.35	.305
2	16.5	0.60	20	2.40	2.39	4.3	17.5	"	0.844	3.42	.602
3	22.5	0.80	20	2.40	2.38	6.0	18.0	"	1.161	4.02	.803
4	2.8	0.10	50	4.52	4.52	1.3	18.5	"	0.131	0.98	.100
5	6.5	0.23	50	4.52	4.51	3.1	18.5	"	0.313	1.52	.230
6	9.9	0.36	50	4.52	4.51	5.0	19.0	"	0.506	1.93	.360
7	2.8	0.10	75	6.29	6.29	1.7	19.0	"	0.123	0.80	.099
8	6.1	0.22	75	6.29	6.28	4.1	19.5	"	0.297	1.26	.218
9	10.6	0.38	75	6.29	6.27	7.1	20.5	"	0.518	1.66	.376
10	2.2	0.08	100	8.05	8.05	1.6	21.0	"	0.090	0.61	.078
11	5.3	0.19	100	8.05	8.04	3.5	21.5	"	0.197	0.90	.186
12	7.4	0.27	100	8.05	8.04	5.9	22.0	"	0.334	1.17	.254
13	1.9	0.07	125	9.80	9.80	1.6	22.5	"	0.074	0.50	.068
14	5.6	0.20	125	9.80	9.80	3.7	23.5	"	0.170	0.76	.194
15	7.3	0.26	125	9.80	9.80	5.7	24.0	"	0.262	0.94	.252
16	5.5	0.20	150	11.56	11.56	1.8	24.5	"	0.069	0.45	.191
17	6.0	0.22	150	11.56	11.56	3.2	25.0	"	0.123	0.59	.210
18	6.3	0.23	150	11.56	11.56	3.9	26.5	"	0.150	0.66	.220

TABLE 8. Actual diameter of pipe = 1.63" Length pipe = 81.8'
Fittings: 2 elbows, 11 nipples (unreamed ends)

No	z" (H_2O)	f	P_1	r_1	r_m	i	T_c	d_o" (orifice)	$\frac{V_o"}{r_m}$	S	f'
1	4.3	0.16	20	2.40	2.40	1.0	19.5	1.75	.189	1.62	.161
2	10.0	0.37	20	2.40	2.40	3.5	19.5	1.50	.360	2.23	.371
3	12.0	0.43	20	2.40	2.39	4.5	19.5	"	.464	2.54	.431
4	3.0	0.11	50	4.52	4.52	1.7	19.5	"	.092	0.82	.110
5	4.1	0.15	50	4.52	4.52	3.7	19.5	"	.202	1.22	.150
6	4.4	0.16	50	4.52	4.51	5.2	19.5	"	.284	1.45	.160
7	2.0	0.07	75	6.29	6.29	1.5	20.0	"	.058	0.55	.069
8	4.2	0.15	75	6.29	6.28	4.0	20.0	"	.157	0.91	.149
9	6.4	0.24	75	6.29	6.27	5.5	23.0	1.75	.395	1.41	.238
10	2.4	0.09	100	8.05	8.05	1.7	23.0	"	.095	0.63	.088
11	4.8	0.18	100	8.05	8.04	3.3	23.5	"	.184	0.87	.176
12	7.9	0.29	100	8.05	8.03	5.2	24.5	"	.290	1.09	.284
13	1.2	0.04	125	9.80	9.80	2.1	24.5	"	.096	0.57	.039
14	7.6	0.27	125	9.80	9.79	4.2	25.0	"	.192	0.81	.261
15	8.5	0.31	125	9.80	9.78	5.8	26.5	"	.265	0.95	.300
16	3.3	0.12	150	11.56	11.56	2.1	27.0	"	.080	0.48	.115
17	5.1	0.19	150	11.56	11.55	4.4	27.0	"	.169	0.70	.184
18	7.8	0.28	150	11.56	11.55	5.8	28.5	"	.223	0.80	.268

TABLE 9. Actual diameter of pipe = 1.63" Length of pipe = 81.8'
Fittings: 2 elbows, 11 nipples (reamed ends).

No.	Z" (H_2O)	f	P_2	r_2	r_m	i	T_c	d_o" (Orifice)	$\frac{V_o}{V_m}$	S	f' Corrected
1	3.6	0.13	20	2.40	2.40	1.3	16.5	1.75	0.249	1.85	.130
2	13.5	0.49	20	2.40	2.39	3.8	16.5	"	0.732	3.19	.491
3	22.6	0.82	20	2.40	2.38	6.1	16.5	"	1.184	4.06	.822
4	2.9	0.10	50	4.52	4.52	2.2	16.5	"	0.223	1.28	.100
5	6.5	0.23	50	4.52	4.52	3.9	17.0	"	0.397	1.71	.230
6	12.1	0.44	50	4.52	4.51	6.3	19.0	"	0.639	2.17	.440
7	0.8	0.03	75	6.29	6.29	2.0	19.5	"	0.144	0.87	.030
8	4.2	0.15	75	6.28	6.28	3.5	20.0	"	0.319	1.46	.148
9	9.2	0.33	75	6.29	6.27	5.9	21.5	"	0.427	1.50	.327
10	1.1	0.04	100	8.05	8.05	1.6	22.0	"	0.090	0.61	.039
11	3.3	0.12	100	8.05	8.04	3.6	22.5	"	0.202	0.91	.117
12	9.1	0.33	100	8.05	8.03	7.2	23.0	"	0.406	1.29	.322
13	1.6	0.06	125	9.80	9.80	1.5	24.0	"	0.068	0.48	.058
14	3.9	0.14	125	9.80	9.79	3.5	24.5	"	0.160	0.74	.135
15	8.1	0.29	125	9.80	9.78	7.0	25.0	"	0.322	1.09	.281
16	1.1	0.04	150	11.56	11.56	2.0	25.0	"	0.077	0.47	.038
17	3.7	0.14	150	11.56	11.55	4.2	26.0	"	0.162	0.68	.134
18	6.6	0.24	150	11.56	11.54	7.7	26.0	"	0.301	0.93	.230

TABLE 10. Actual diameter of pipe = 1.63". Length of pipe = 85.5'
Fittings: 12 elbows, 11 nipples (reamed ends).

No	Z" (H_2O)	f	P_2	r_2	r_m	i	T_c	d_o" (orifice)	$\frac{V_o}{V_m}$	S	f' Corrected
1	4.5	0.17	20	2.40	2.40	0.9	19.0	1.75	0.176	1.56	.170
2	14.6	0.53	20	2.40	2.39	3.1	21.0	"	0.600	2.88	.532
3	21.4	0.77	20	2.40	2.38	4.6	21.0	"	0.897	3.53	.772
4	5.9	0.21	50	4.52	4.51	2.4	21.0	"	0.245	1.34	.210
5	9.8	0.35	50	4.52	4.52	3.7	21.0	"	0.381	1.67	.350
6	13.3	0.48	50	4.52	4.50	5.2	22.0	"	0.537	1.99	.480
7	4.6	0.17	75	6.29	6.29	2.4	22.0	"	0.176	0.96	.168
8	7.8	0.28	75	6.29	6.28	4.5	23.0	"	0.330	1.32	.278
9	12.2	0.44	75	6.29	6.27	6.2	24.0	"	0.457	1.55	.435
10	2.8	0.10	100	8.05	8.05	1.8	25.0	"	0.100	0.65	.098
11	6.8	0.25	100	8.05	8.04	4.1	25.0	"	0.185	0.98	.249
12	9.3	0.34	100	8.05	8.03	5.6	26.0	"	0.319	1.15	.332
13	3.3	0.12	125	9.80	9.80	2.4	26.0	"	0.118	0.63	.116
14	4.8	0.18	125	9.80	9.79	3.3	27.0	"	0.150	0.71	.174
15	6.6	0.24	125	9.80	9.78	4.3	27.0	"	0.195	0.81	.232
16	4.1	0.15	150	11.56	11.56	2.2	28.0	"	0.084	0.49	.144
17	2.6	0.09	150	11.56	11.56	2.0	29.0	"	0.076	0.47	.086
18	9.8	0.35	150	11.56	11.55	7.0	30.0	"	0.269	0.88	.345

Table 11. Actual diameter of pipe = 1.63". Length of pipe = 89'
Fittings: 2 elbows, 5 return bends (open pattern), 6 nipples (reamed ends).

No.	Z'' (H_2O)	f'	P_2	r_2	r_m	i	T_c	d_o'' (Orifice)	$\frac{V_o''}{V_m}$	S	f' Corrected
1	10.4	0.38	20	2.40	2.38	2.2	23.0	1.75	0415	2.40	.380
2	21.1	0.76	20	2.40	2.37	3.9	23.0	"	0.741	3.22	.762
3	31.0	1.12	20	2.40	2.37	6.3	23.0	"	1.195	4.09	1.123
4	4.0	0.14	50	4.52	4.52	1.5	23.0	"	0.149	1.05	.140
5	6.8	0.25	50	4.52	4.51	2.9	23.0	"	0254	1.44	.250
6	13.0	0.47	50	4.52	4.50	5.2	23.0	"	0.517	1.95	.470
7	2.5	0.09	75	6.29	6.29	1.4	24.0	"	0.099	0.72	.089
8	6.6	0.24	75	6.29	6.28	3.5	24.0	"	0.250	1.15	.238
9	15.3	0.55	75	6.29	6.27	7.6	25.0	"	0.547	1.70	.545
10	2.1	0.08	100	8.05	8.05	1.5	25.0	"	0.083	0.58	.078
11	4.6	0.17	100	8.05	8.04	3.0	26.0	"	0.166	0.83	.166
12	9.7	0.35	100	8.05	8.03	6.1	26.0	"	0.341	1.19	.342
13	2.7	0.10	125	9.80	9.80	2.0	27.0	"	0.090	0.55	.097
14	5.3	0.19	125	9.80	9.79	3.3	27.0	"	0.177	0.77	.184
15	9.6	0.35	125	9.80	9.78	6.8	27.0	"	0.310	1.02	.339
16	2.3	0.08	150	11.56	11.56	2.0	27.0	"	0.077	0.47	.077
17	3.8	0.14	150	11.56	11.55	3.2	28.0	"	0.123	0.59	.134
18	7.0	0.25	150	11.56	11.54	5.7	28.0	"	0.220	0.79	.239

TABLE 12. Actual diameter of pipe = 1.63". Length pipe = 86'.
Fittings: 2 elbows, 4 globe valves, 5 nipples (ends reamed.)

No.	Z'' (H_2O)	f	P_2	r_2	r_m	i	T_c	d_o'' (Orifice)	$\frac{V_o''}{V_m}$	S	f' Corrected
1	18.5	0.67	20	2.40	2.38	1.6	24.0	1.75	0.301	2.05	.672
2	30.8	1.11	20	2.40	2.37	3.0	24.0	"	0.568	2.82	1.112
3	31.0	1.12	20	2.40	2.37	2.8	24.0	"	0.530	2.72	1.123
4	11.7	0.42	50	4.52	4.50	2.0	22.0	"	0.206	1.23	.420
5	16.5	0.60	50	4.52	4.49	2.8	22.0	"	0.282	1.44	.600
6	24.4	0.88	50	4.52	4.48	4.3	22.0	"	0435	1.79	.880
7	9.2	0.33	75	6.29	6.29	2.2	22.0	"	0.160	0.92	.327
8	13.8	0.50	75	6.29	6.25	3.2	22.0	"	0.232	1.01	.495
9	20.7	0.75	75	6.29	6.25	4.7	22.0	"	0.341	1.34	.743
10	6.9	0.25	100	8.05	8.05	2.0	22.0	"	0.116	0.55	.244
11	11.0	0.40	100	8.05	8.04	3.2	23.0	"	0.185	0.87	.391
12	16.0	0.58	100	8.05	8.01	4.6	23.0	"	0267	1.05	.567
13	4.5	0.16	125	9.80	9.80	1.6	24.0	"	0.048	0.40	.155
14	8.3	0.30	125	9.80	9.79	2.9	24.0	"	0.137	0.68	.290
15	13.9	0.50	125	9.80	9.78	4.7	24.0	"	0.218	0.87	.480
16	4.4	0.16	150	11.56	11.56	1.8	25.0	"	0.088	0.45	.153
17	8.2	0.30	150	11.56	11.55	3.3	25.0	"	0.132	0.61	.287
18	11.5	0.42	150	11.56	11.54	4.5	25.0	"	0.180	0.72	.402

TABLE 13. Actual diameter of pipe = 1.63" Length pipe = 88'
Fittings: 8-45° elbows, 7 nipples (reamed ends).

No.	z' (H_2O)	f	ℓ_2	r_2	r_m	i	T_c	d_o'	$\frac{V_o^2}{r_m}$	S	f'
1	7.4	0.27	20	2.40	2.40	1.5	23	1.75	0.284	2.0	0.271
2	13.2	0.48	20	2.40	2.39	2.9	23	"	0.547	2.8	0.492
3	19.2	0.69	20	2.40	2.38	4.3	23	"	0.832	3.4	0.692
4	2.5	0.09	50	4.52	4.52	1.0	23	"	0.100	0.9	0.090
5	8.5	0.31	50	4.52	4.51	3.6	23	"	0.368	1.6	0.310
6	12.8	0.46	50	4.52	4.50	6.6	23	"	0.575	2.1	0.460
7	2.4	0.09	75	6.29	6.29	1.4	23	"	0.100	0.7	0.089
8	6.5	0.24	75	6.29	6.28	3.7	23	"	0.271	1.2	0.238
4	10.5	0.38	75	6.29	6.27	5.7	23	"	0.420	1.5	0.376
10	3.0	0.11	100	8.05	8.05	1.7	24	"	0.094	0.6	0.107
11	4.6	0.17	100	8.05	8.04	3.2	24	"	0.184	0.9	0.166
12	7.1	0.26	100	8.05	8.03	4.8	24	"	0.277	1.1	0.254
13	1.9	0.07	125	9.80	9.80	1.6	25	"	0.075	0.5	0.068
14	4.0	0.15	125	9.80	9.79	3.3	25	"	0.155	0.7	0.145
15	5.9	0.21	125	9.80	9.78	4.8	25	"	0.224	0.9	0.203
16	1.8	0.07	150	11.56	11.56	1.7	26	"	0.065	0.5	0.067
17	3.8	0.14	150	11.56	11.55	3.5	25	"	0.140	0.6	0.134
18	5.8	0.21	150	11.56	11.54	5.6	25	"	0.222	0.8	0.201

TABLE 14. Actual diameter of pipe = 2.08". Length pipe = 92'4
Fittings: 2-elbows, 10 nipples (unreamed ends)

No.	z" (H_2O)	f	P_2	r_2	r_m	i	T_c	d_o" (Orifice)	$\frac{V_a^2}{r_m}$	S	f' (Corrected)
1	4.4	0.16	10	1.71		2.6	20	1.75	0.456	11	0.16
2	10.1	0.37	12	1.85		6.7	20	"	1.674	40	0.37
3	2.4	0.09	30	3.13		2.8	20	"	0.405	10	0.09
4	4.5	0.16	30	3.13		5.1	20	"	0.746	21	0.16
5	11.6	0.42	30	3.13		7.6	21	2.00	1.903	33	0.42
6	2.5	0.09	30	3.13		1.3	21	"	0.141	11	0.09
7	2.1	0.08	50	4.55		1.9	22	"	0.316	9	0.07
8	6.8	0.25	50	4.55		6.2	22	"	1.059	20	0.24
9	1.9	0.07	75	6.32	same as 14	2.6	23	"	0.319	9	0.07
10	2.8	0.10	75	6.32		3.6	23	"	0.435	11	0.10
11	4.3	0.16	75	6.32		5.3	24	"	0.649	14	0.15
12	1.7	0.06	100	8.09		2.8	24	"	0.259	8	0.06
13	2.5	0.09	100	8.09		3.9	25	"	0.461	9	0.09
14	4.3	0.16	100	8.09		6.3	25	"	0.690	11	0.15

TABLE 15. Actual diameter of pipe = 2.08" Length pipe = 82'6
Fittings: 2-elbows, 1 nipple (reamed ends)

No	z" (H_2O)	f	P_2	r_2	r_m	i	T_c	d_o"	$\frac{V_a^2}{r_m}$	S	f'
1	9.6	0.33	12	1.85		2.6	24	2.0	1.126	33	0.330
2	12.2	0.44	10	1.71		3.2	24	"	1.477	39	0.442
3	16.0	0.58	13	1.93		4.9	24	"	2.015	43	0.580
4	3.4	0.12	30	3.13		1.7	24	"	0.436	16	0.123
5	6.2	0.22	30	3.13		3.2	24	"	0.807	21	0.224
6	12.8	0.46	30	3.13		6.4	24	"	1.639	31	0.464
7	2.1	0.08	50	4.55		1.6	24	"	0.273	10	0.075
8	3.3	0.12	50	4.55	same as 14	2.9	23	"	0.512	14	0.118
9	5.8	0.21	50	4.55		4.2	23	"	0.741	14	0.206
10	1.4	0.05	75	6.32		1.5	24	"	0.184	7	0.050
11	3.0	0.11	75	6.32		3.0	25	"	0.377	10	0.099
12	4.1	0.15	75	6.32		4.6	25	"	0.581	13	0.148
13	0.7	0.03	100	8.09		1.1	25	"	0.102	5	0.024
14	1.9	0.07	100	8.09		2.4	25	"	0.238	7	0.066
15	3.1	0.11	100	8.09		3.8	25	"	0.370	9	0.107

TABLE 16. Actual diameter of pipe = 2.08". Length pipe = 92.4'.
Fittings: 2-elbows, 10 nipples (reamed ends).

No.	Z'' (H_2O)	f	P_2	r_2	r_m	i	T_c	d_o'' (Orifice)	$\frac{V_a^2}{r_m}$	S	f' (Corrected)
1	5.4	0.19	15	2.06		1.8	23	2.0	0.674	24	
2	11.3	0.41	16	2.13		3.9	24	"	1.432		
3	16.6	0.60	15	2.06		5.4	24	"	2.084	43	
4	1.9	0.07	40	3.82		1.2	23	"	0.249	12	
5	4.5	0.16	40	3.82	"	2.9	23	"	0.592	19	
6	7.9	0.25	40	3.82		5.0	23	"	1.048	20	
7	1.8	0.07	65	5.60	same as	1.2	24	"	0.163	7	
8	3.4	0.12	65	5.60		3.5	24	"	0.496	13	
9	5.3	0.19	65	5.60		5.0	24	"	0.709	15	same as f
10	0.8	0.03	100	8.09		1.3	24	"	0.122	5	
11	1.5	0.05	100	8.09		2.7	24	"	0.265	6	
12	2.7	0.10	100	8.09		3.9	24	"	0.372	9	same as f
1											

TABLE 17. Actual diameter of pipe = 2.08" Length pipe = 90.7'
Fittings: 10-elbows, 9 nipples (reamed ends)

No	Z'' (H_2O)	f	P_2	r_2	r_m	i	T_c	d_o''	$\frac{V_a^2}{r_m}$	S	f'
1	6.4	0.28	15	2.06		1.7	24	2.0	0.523	23	
2	13.1	0.47	15	2.06		3.5	24	"	1.334	33	
3	21.0	0.76	15	2.06		5.6	24	"	2.148	42	
4	2.3	0.08	40	3.82		2.2	24	"	0.449	15	
5	6.7	0.24	40	3.82		4.5	24	"	0.929	21	"
6	12.6	0.46	40	3.82	same as 4"	6.2	24	"	1.294	25	
7	2.0	0.07	65	5.60		1.6	24	"	0.220	8	same as f
8	4.1	0.15	65	5.60		3.3	25	"	0.462	12	
9	7.4	0.27	65	5.60		5.1	25	"	0.723	15	
10	1.1	0.04	100	8.09		1.4	25	"	0.137	6	same as
11	2.1	0.08	100	8.09		2.4	25	"	0.236	7	
12	3.9	0.14	100	8.09		4.3	25	"	0.442	10	

TABLE 18. Actual diameter of pipe = 2.08" Length pipe = 87.6'.
Fittings: 2-elbows, 5 return bends, 6 nipples (reamed ends).

No.	Z'' (H_2O)	f	P_2	γ_2	γ_m	i	T_c	d_o'' (Orifice)	$\frac{V_a^2}{\gamma_m}$	S	f' Corrected
1	7.6	0.28	11	1.68		2.0	24	2.0	0.926	31	
2	13.5	0.49	13	1.89		3.9	23	"	1.627	39	
3	19.8	0.72	20	2.42		7.5	23	"	2.475	43	
4	2.1	0.08	40	3.82		1.5	23	"	0.191	14	
5	6.2	0.22	40	3.82		3.9	23	"	0.815	23	
6	12.4	0.50	40	3.82	Same as #1	7.6	24	"	1.574	32	
7	0.8	0.03	80	6.67		1.1	24	"	0.126	6	Same as #1
8	3.3	0.12	80	6.67		3.6	24	"	0.341	8	
9	6.1	0.22	80	6.67		6.4	24	"	0.759	11	
10	0.6	0.02	100	8.09		1.0	24	"	0.099	5	
11	2.1	0.08	100	8.09		2.9	24	"	0.286	8	
12	3.3	0.12	100	8.09		4.1	25	"	0.405	10	

TABLE 19. Actual diameter of pipe = 2.08" Length pipe = 86.6'.
Fittings: 2-elbows, 4 globe valves, 5 nipples (reamed ends.)

No.	z" (H_2O)	f	P_2	r_2	r_m	i	T_c	d_o" (Orifice)	$\frac{V_a^2}{r_m}$	S	f' (corrected)
1	24.9	0.90	11	1.78		2.9	23	2.0	.130	13	
2	15.0	0.54	10	1.71		1.6	24	"	.590	35	
3	43.7	1.58	20	2.42		6.7	26	"	.216	39	
4	6.1	0.22	40	3.85		1.6	26	"	.034	13	
5	15.3	0.58	90	3.85		4.1	26	"	.879	19	
6	30.0	1.08	40	3.85	Same as r_2	7.4	26	"	.143	26	Same as f
7	3.6	0.13	75	6.32		1.5	26	"	.180	6	
8	9.0	0.33	75	6.32		3.5	26	"	.044	11	
9	17.9	0.65	75	6.32		6.6	26	"	.821	15	
10	2.0	0.07	100	8.10		1.2	26	"	.012	6	
11	5.8	0.21	100	8.10		3.1	27	"	.030	9	
12	10.9	0.39	100	8.10		5.5	27	"	.532	11	

TABLE 20. Actual diameter of pipe = 2.08" Length pipe = 88.6
Fittings: 8-45° elbows, 7 nipples (reamed ends.)

No.	z" (H_2O)	f	P_2	r_2	r_m	i	T_c	d_o"	$\frac{V_a^2}{r_m}$	S	f'
1	8.9	0.32	10	1.71		2.2	23	2.0	.102	32	
2	17.1	0.62	15	2.07		5.5	22	"	.212	43	
3	20.9	0.76	20	2.42		7.7	22	"	.253	43	
4	1.2	0.05	50	4.56		0.9	22	"	.158	19	
5	4.3	0.16	50	4.55		3.2	22	"	.553	15	
6	8.6	0.31	50	4.55	Same as r_2	5.9	22	"	.116	19	Same as f
7	0.7	0.03	75	6.32		0.9	22	"	.120	6	
8	2.5	0.09	75	6.32		2.6	22	"	.327	9	
9	4.6	0.17	75	6.32		4.9	23	"	.617	13	
10	0.6	0.02	100	8.10		1.2	23	"	.108	4	
11	1.9	0.07	100	8.10		2.6	24	"	.256	8	
12	3.1	0.11	100	8.10		4.0	24	"	.402	9	

Table "A" Equations and Results.

Plate from Table No.	Size Pipe	Length Pipe	Fittings. L	D	U	R	G	B	N	Equation.
1	1"	80'	2	—	26	—	—	—	9.03	80p+2L+26U = 9.03
2	"	"	2	—	—	26	—	—	6.80	80p+2L+26R = 6.80
3	"	"	10	—	18	—	—	—	11.07	80p+10L+18U = 11.07
4	"	"	2	—	2	—	—	—	6.55	80p+2L+2U = 6.55
5	"	"	2	—	10	—	5	—	18.30	80p+2L+10U+5G = 18.30
6	"	"	2	—	—	14	—	6	7.53	80p+2L+6B+14R = 7.53

Fitting	Loss of Pressure	Equivalent Length of Pipe.
1' of Pipe	0.070 $\frac{V^2}{r}$	—
L	0.359 "	5.14'
D	—	—
U	0.103 "	1.47
R	0.0175 "	0.25
G	2.185 "	31.21
B	.157 "	2.24

Symbols.

L = 1-90° Elbow.
D = 1-45° "
U = 1-Unreamed end.
R = 1-reamed "
G = 1-Globe Valve.
B = 1-Return Bend
P = 1-Foot of Pipe.

Table "B" Equations and Results.

Plate from Table No	Size of Pipe	Length of Pipe	Fittings.						N	Equation.
			L	D	U	R	G	B		
8	1.5"	81.8	2	—	22	—	—	—	1.00	$81.8P+2L+22U=1.00$
9	"	81.8	2	—	—	—	—	—	0.670	$81.8P+2L=.670$
10	"	85.5	12	—	—	—	—	—	1.015	$85.5P+12L=1.015$
11	"	89.0	2	—	—	—	—	5	1.00	$89P+2L+5B=1.00$
12	"	86.0	2	—	—	—	4	—	2.15	$86P+2L+4G=2.15$
13	"	88.0	—	8	—	—	—	—	0.915	$88P+8D=0.915$

Fitting	Loss of Pressure	Equivalent Length of Pipe in feet.
1' of Pipe	$.0074\ \frac{Va^2}{r}$	—
L	.0323 "	4.36
D	.0330 "	4.46
U	.015 "	0.20
R	—	—
G	.3622 "	48.90
B	.0553 "	7.47

Symbols.

L = 1 – 90° Elbow.
D = 1 – 45° "
U = 1 – Unreamed end.
R = 1 – Reamed "
G = 1 – Globe Valve.
B = 1 – Return Bend.
P = 1 – Foot of Pipe.

Table "C" Equations and Results.

Plate from Table No.	Size of Pipe	Length of Pipe	Fittings						N	Equation.
			L	D	U	R	G	B		
14	2"	92.4	2	—	20	—	—	—	.280	92.4P+2L+20U = .280
15	"	82.6	2	—	—	2	—	—	.219	82.6P+2L+2R = .219
16	"	92.4	2	—	—	20	—	—	.275	92.4P+2L+20R = .275
17	"	90.7	10	—	—	18	—	—	.336	90.7P+10L+18R = .336
18	"	87.6	2	—	—	12	—	5	.290	87.6P+2L+5B+12R = .290
19	"	86.6	2	—	—	10	4	—	.729	86.6P+2L+4G+10R = .729
20	"	88.6		8		14	—	—	.290	88.6P+8D+14R = .290

Fitting	Loss of Pressure	Equivalent Length of Pipe in feet.
1' of Pipe	.0024 $\frac{V_g^2}{r}$	—
L	.0086 "	3.58
D	.0065 "	2.70
U	.0020 "	0.83
R	.0018 "	0.75
G	.1215 "	50.60
B	.0082	3.42

Symbols.

L = 1-90° Elbow.
D = 1-45° "
U = 1-Unreamed end.
R = 1-Reamed "
G = 1-Globe Valve.
B = 1-Return Bend.
P = 1-Foot of Pipe.

TABLE (D)

Coefficients for 1, 1½ and 2 inch pipe.

Diameter of pipe							
	Nominal	1"		1½"		2"	
	Actual		1.07"		1.63"		2.08"
Lost pressure 1 ft. pipe		0.070	0.070	0.0074	0.0074	0.0024	0.0024
Coefficient		0.070	0.099	0.052	0.085	0.077	0.093

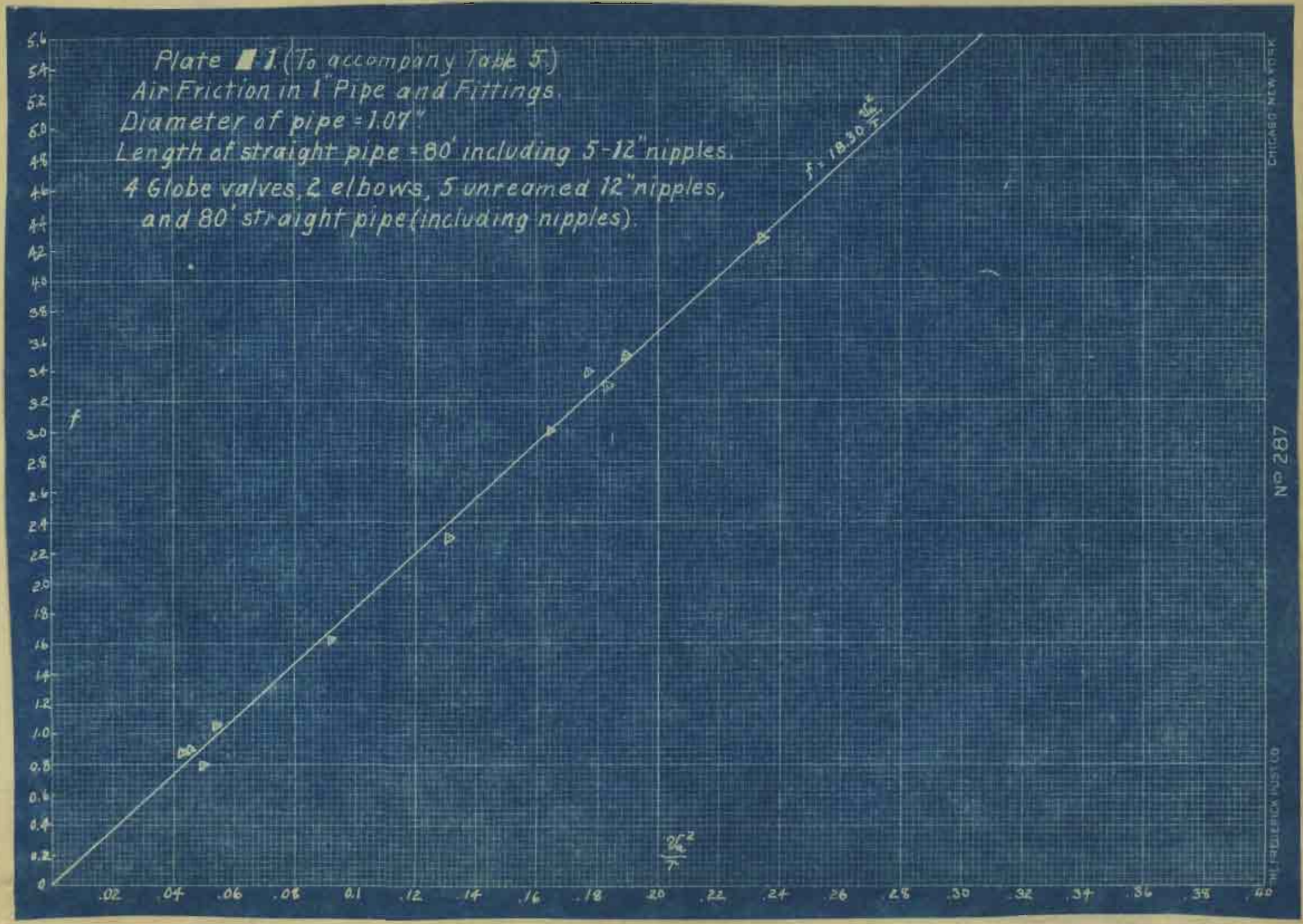
Plate 1. (To accompany Table 5.)
Air Friction in 1" Pipe and Fittings.
Diameter of pipe = 1.07"
Length of straight pipe = 80' including 5-12" nipples.
4 Globe valves, 2 elbows, 5 unreamed 12" nipples,
and 80' straight pipe (including nipples).
f = 18.30
f
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
.02
.04
.06
.08
0.1
.12
.14
.16
.18
.20
.22
.24
.26
.28
.30
.32
.34
.36
.38
.40
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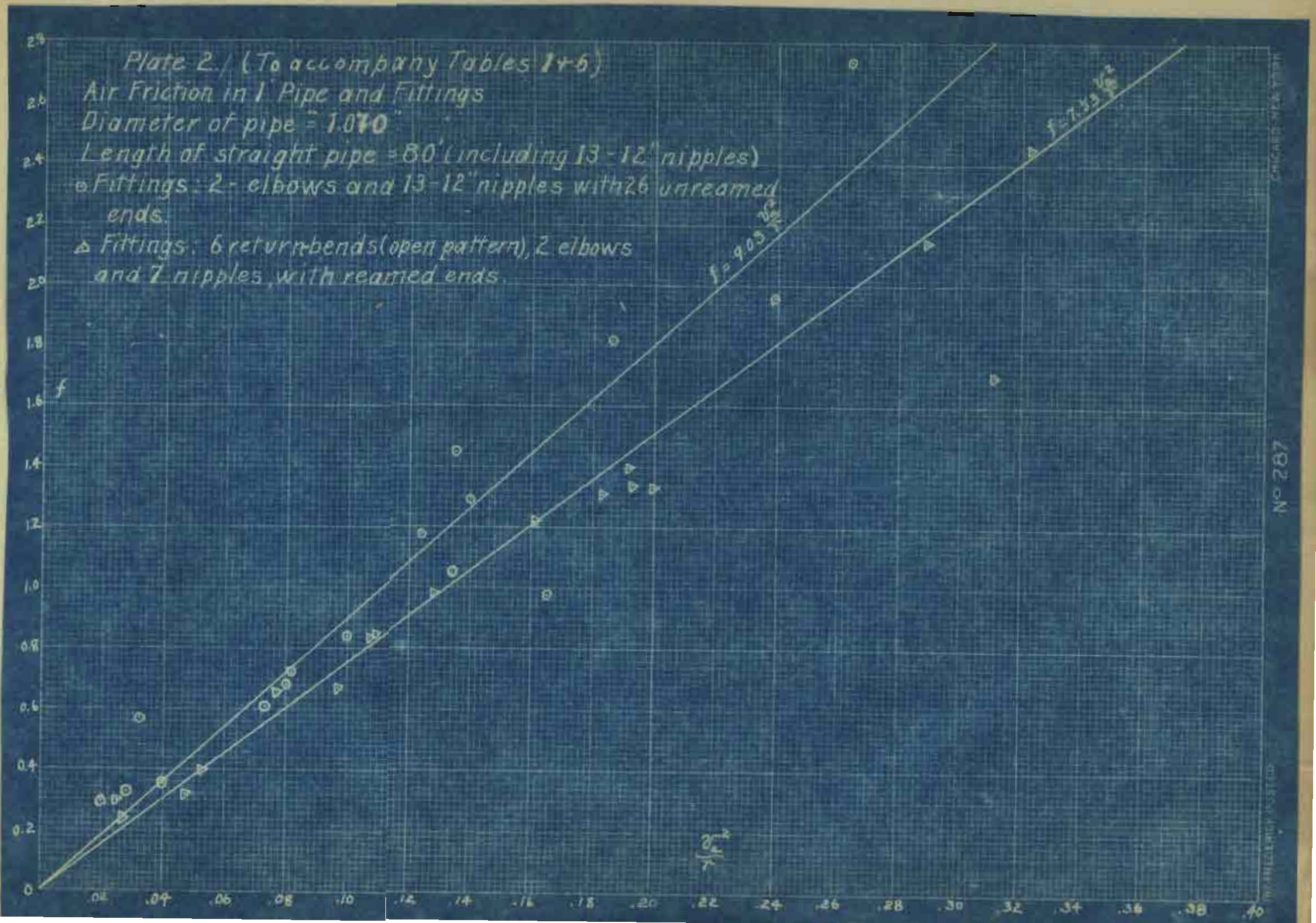
Plate 2. (To accompany Tables 1+5)
Air Friction in 1" Pipe and Fittings
Diameter of pipe = 1.070"
Length of straight pipe = 80' (including 13 - 12" nipples)
o Fittings: 2 - elbows and 13 - 12" nipples with 26 unreamed ends.
Δ Fittings: 6 return bends (open pattern), 2 elbows and 7 nipples, with reamed ends.
f = 9.03 √(d/V)
f = 7.33 √(d/V)
f
d/V²
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
.24
.26
.28
.30
.32
.34
.36
.38
.40
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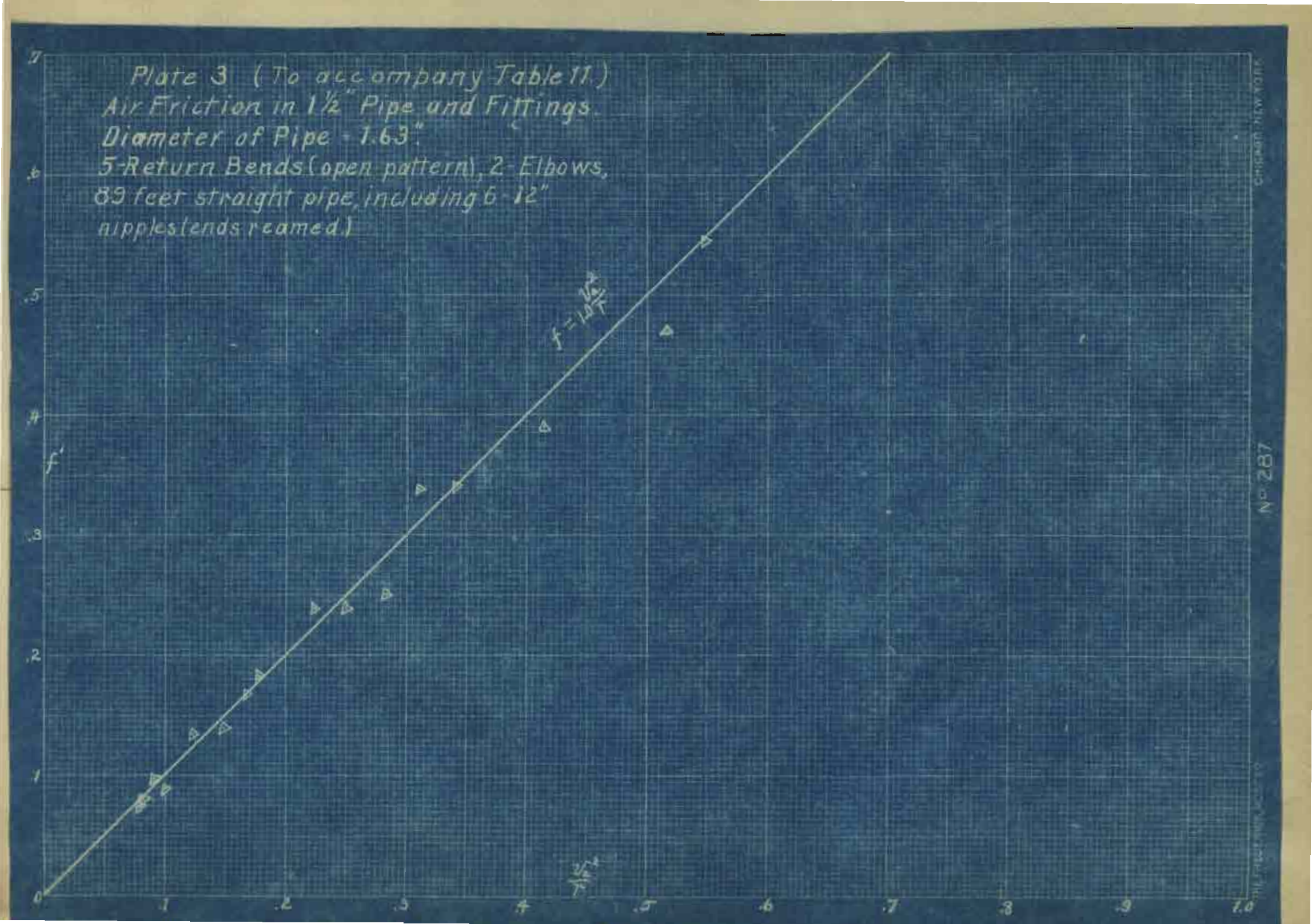


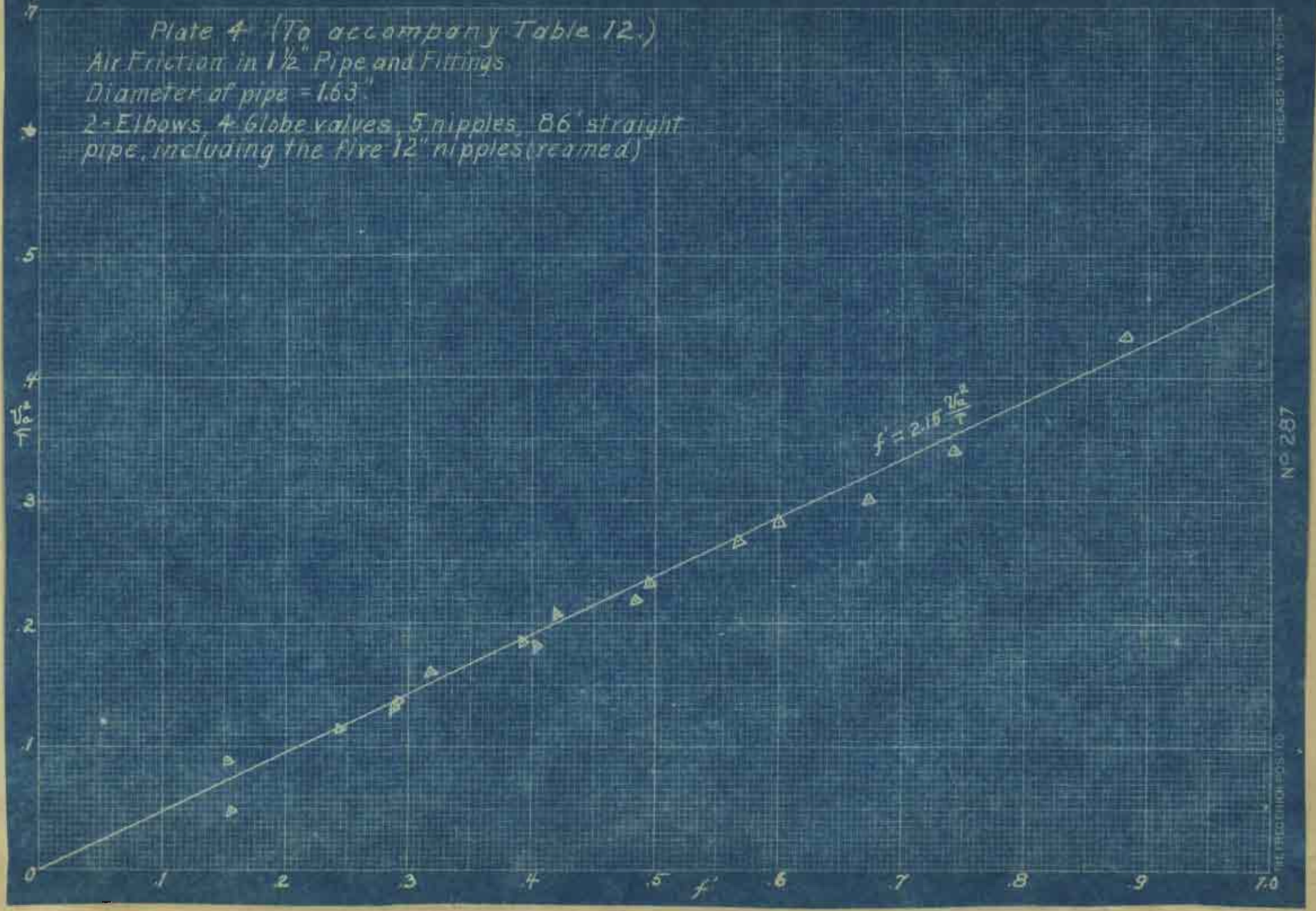
Plate 3 (To accompany Table 11.)
Air Friction in 1½" Pipe and Fittings.
Diameter of Pipe - 1.63".
5-Return Bends (open pattern), 2-Elbows,
89 feet straight pipe, including 6-12"
nipples (ends reamed.)
f = 1.0 √f'
f'
√f'/V
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
No. 287

Plate 4 (To accompany Table 12.)

Air Friction in 1½" Pipe and Fittings

Diameter of pipe = 1.63"

2 - Elbows, 4 Globe valves, 5 nipples, 86' straight pipe, including the five 12" nipples (reamed)



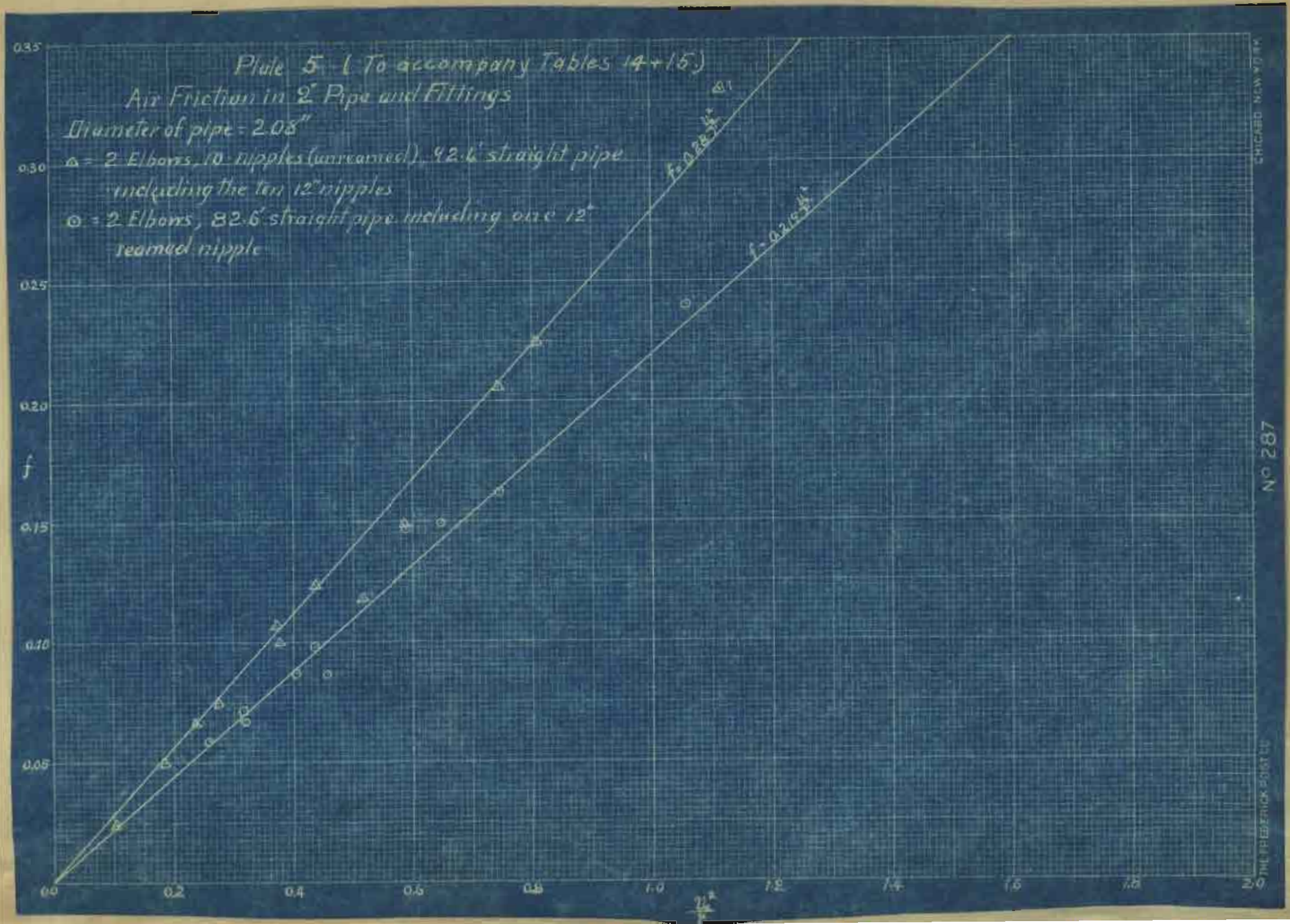


Plate 5 (To accompany Tables 14 + 15)
Air Friction in 2" Pipe and Fittings
Diameter of pipe = 2.08"
△ = 2 Elbows, 10 nipples (unreamed), 92.6' straight pipe including the ten 12" nipples
⊙ = 2 Elbows, 82.6' straight pipe including one 12" reamed nipple
f = 0.28 V^-0.25
f = 0.215 V^-0.25
f
V ft.
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
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Plate 6. (To accompany Tables 19+20.)

Air Friction in 2" Pipe and Fittings

Diameter of pipe = 2.08"

⊙ = 2 Elbows and 4 Globe-Valves on 86.6' of straight pipe, including 5 reamed nipples

△ = 8 - 45° Elbows on 88.6' of straight pipe, including 7 reamed nipples