



107
621
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AN EXPERIMENTAL STUDY OF THE
COEFFICIENT OF HEAD LOSS DUE
TO FRICTION THROUGH SMALL
DIAMETER PIPE FITTINGS

Thesis for the Degree of B. S.

J. C. Erkfitz

C. F. Clark

1935

THESIS

An Experimental Study of the Coefficient of
Head Loss Due to Friction Through Small
Diameter Pipe Fittings

A Thesis Submitted to
The Faculty of
MICHIGAN STATE COLLEGE
of
AGRICULTURE AND ALLIED SCIENCES

By

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Candidates for the Degree of
Bachelor of Science

June 1935

THESE

ACKNOWLEDGEMENT

We wish to acknowledge at this time and to thank all the members of the Civil Engineering Department for aid and criticism during the past term of experimentation. We also wish to thank the Department for the loan of all equipment, materials and for the use of the Hydraulic Laboratory.

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We chose "The Study of the Coefficient of Head Loss Due to Friction in Small Diameter Pipe Fittings" as our thesis because we were unable to find any experimental data on this subject. The object of our work was to obtain coefficients of reasonable enough accuracy for use in finding the head loss through any pipe system.

The essential apparatus used in this experiment are as follows;

Fittings to be tested

2", 1", $\frac{3}{4}$ ", $\frac{1}{2}$ " Diameters

Mercury Manometer

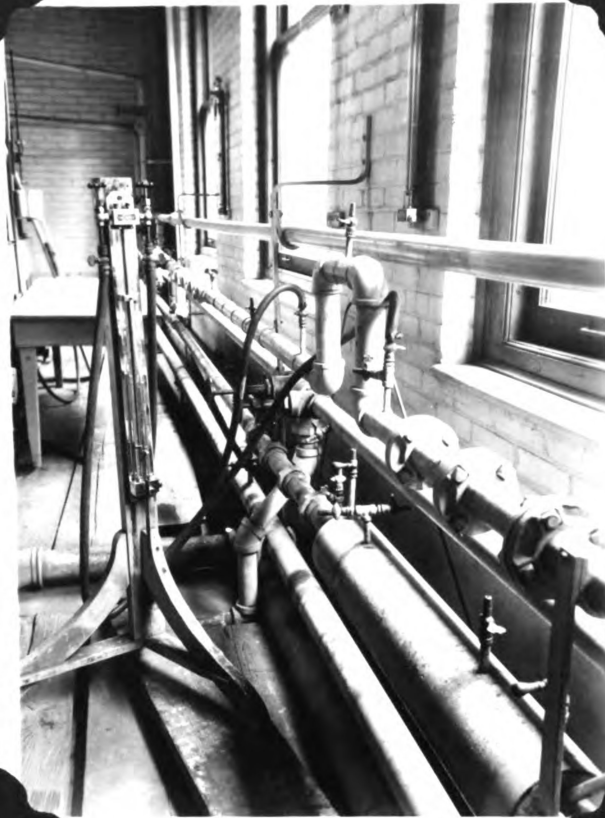
Stop Watch

Platform Scale

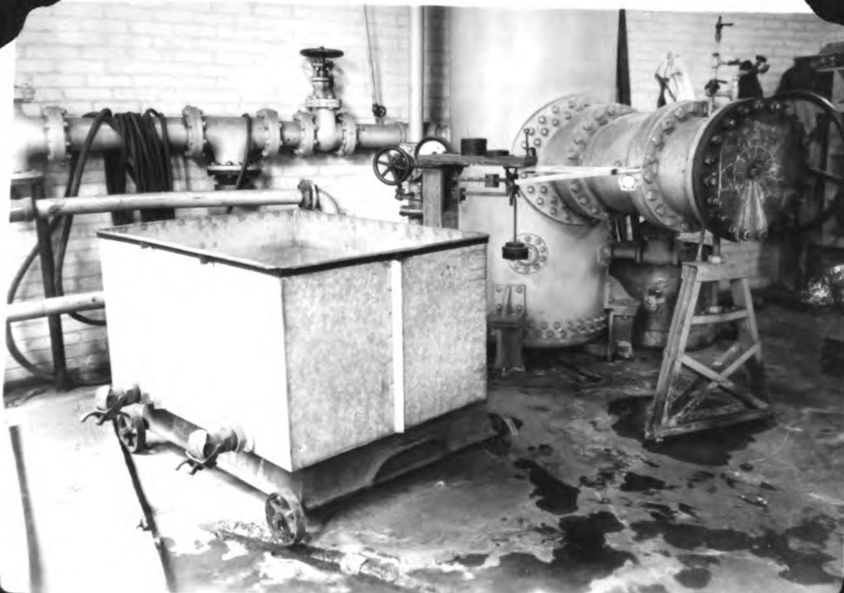
Water Container

In testing these fittings we connected four fittings of similar type and size in a series, as shown in the accompanying photograph(A). This picture also shows how the manometer was connected to measure the difference in water pressure between the point at which the water entered the fittings and the point at which it left. Before any readings were taken on the manometer we made sure that all the air was out of the line, connecting hose, and manometer. The discharge was measured by timing a certain quantity of

of flow. The water emptied into a metal tank that rested upon the platform scale. This apparatus is shown in photograph (B). Our device for timing can also be seen. It was secured to the frame of the scale and consisted of two pieces of wood in a scissor-like arrangement. The balance arm of the scale would, upon rising, push up the lower piece causing the stop watch to start or stop. A definite quantity of water was allowed to run into the tank and the time it took to discharge this amount was measured with the stop watch. This procedure was followed using different velocities of water, ranging from the lowest measureable velocity to the highest, for each type and size of fitting. Three readings of time and head loss were taken for each velocity and the average of these was used in computing the coefficient of head loss.



Photograph "A"



Photograph "B"

1. 01000000 00000000 00000000 00000000

November 1974

SIMPLE COMPUTATIONS

for

2" STRAIGHT TUBES

DISCHARGE

$$\frac{\text{WEIGHT OF WATER - lbs.}}{62.5 \times \text{TIME -secs.}}$$

$$\frac{800}{62.5 \times 187.5}$$

.0683 C.F.S.

VELOCITY

$$\frac{\text{DISCHARGE - C.F.S.}}{\text{CROSS SECTIONAL AREA - sq. ft.}}$$

$$\frac{.0683}{.0218}$$

3.13 FT./SEC.

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

$$\frac{9.7969}{62.4}$$

.152

1" Hg.

$$\frac{\text{DENSITY OF MERCURY} - \text{DENSITY OF WATER}}{12}$$

$$\frac{13.6 - 1}{12} \quad 1.05 \text{ FEET OF WATER}$$

HEAD LOSS

MANOMETER READING x 1.05

$$.22 \times 1.05 \quad .231 \text{ FEET OF WATER}$$

COEFFICIENT
OF HEAD LOSS

$$\frac{\text{HEAD LOSS - FEET OF WATER}}{v^2/2g \times \text{NUMBER OF FITTINGS}}$$

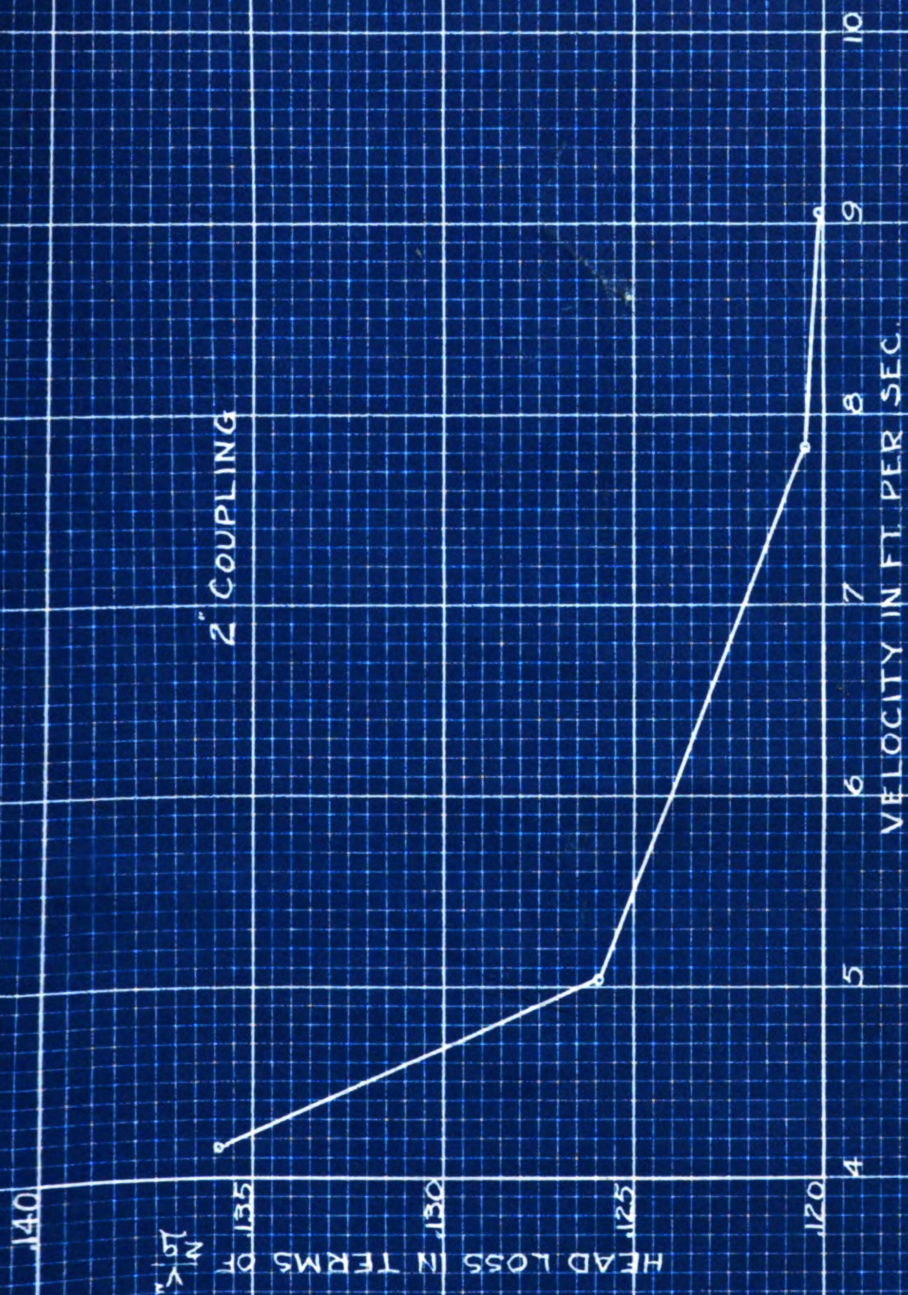
$$\frac{.231}{.152 \times 4} \quad .380 \text{ TERMS OF } \frac{v^2}{2g}$$

HEAD LOSS IN TERMS OF $\frac{V^2}{2g}$

2" COUPLINGS	-----	.126
2" UNIONS	-----	.214
2" ELBOWS	-----	.726
2" STRAIGHT TEES	-----	.260
2" 90 TEES	-----	.873
2" FLANGES	-----	.190
2" GLOBE VALVES	-----	6.520
1" COUPLINGS	-----	.409
1" UNIONS	-----	.836
1" ELBOWS	-----	.701
1" STRAIGHT TEES	-----	.303
1" 90 TEES	-----	1.300
$\frac{3}{4}$ " COUPLINGS	-----	.2467
$\frac{3}{4}$ " UNIONS	-----	.3413
$\frac{3}{4}$ " ELBOWS	-----	.727
$\frac{3}{4}$ " STRAIGHT TEES	-----	.493
$\frac{3}{4}$ " 90 TEES	-----	1.297
$\frac{1}{2}$ " COUPLINGS	-----	.205
$\frac{1}{2}$ " UNIONS	-----	.213
$\frac{1}{2}$ " ELBOWS	-----	.347
$\frac{1}{2}$ " STRAIGHT TEES	-----	.238
$\frac{1}{2}$ " 90 TEES	-----	.827

2" COUPLINGS

[illegible]

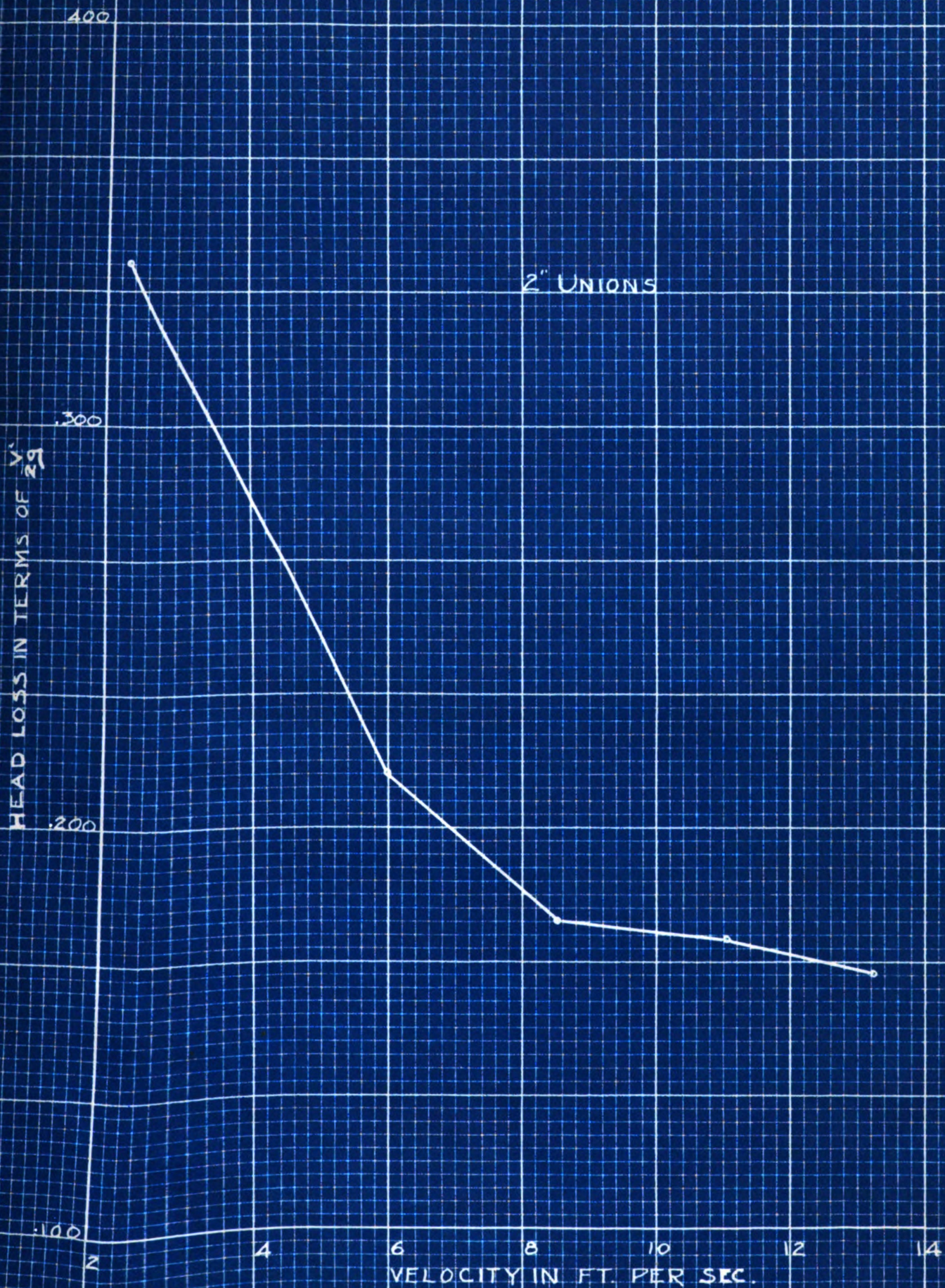


2" UNIONS

Wgt. Water #	Time in Sec.	Head Loss in.Hg.	Head Loss ft.H ₂ O	Vel. in ft/sec.	$\frac{V^2}{2g}$	C.F.S.	Coef. per Fitt.
800	250.0	0.22					
800	246.0	0.24					
800	243.2	0.25					
Aver.	247.1	0.24	0.249	2.38	.1876	.0518	.238
800	84.3	0.51					
800	89.1	0.46					
800	98.1	0.38					
Aver.	90.5	0.45	0.474	5.98	.5570	.1305	.213
800	67.2	0.82					
800	69.2	0.75					
800	72.0	0.70					
Aver.	69.5	0.76	0.788	8.46	1.1100	.1845	.177
800	55.0	1.17					
800	52.8	1.23					
800	52.2	1.29					
Aver.	53.3	1.23	1.290	11.00	1.8400	.2400	.173
800	45.4	1.67					
800	44.1	1.78					
800	44.2	1.78					
Aver.	44.6	1.74	1.825	13.20	2.7100	.2875	.168

Final Average Loss per Fitting .214

7b



$\mathcal{E}(a)$

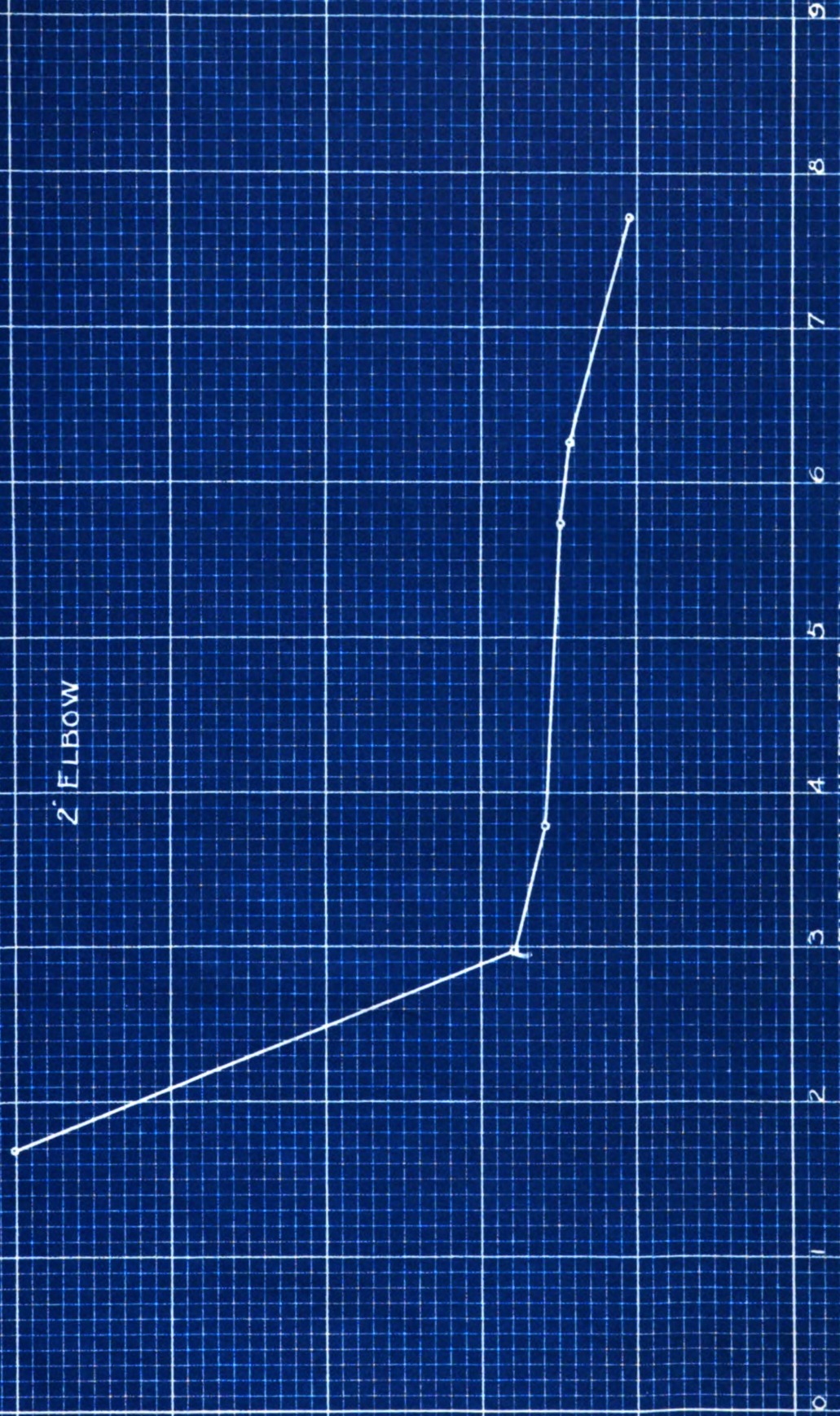
2" ELBOWS

[illegible]

2" ELBOW

HEAD LOSS IN TERMS OF
 $\frac{V^2}{2g}$

VELOCITY IN FT. PER SEC.

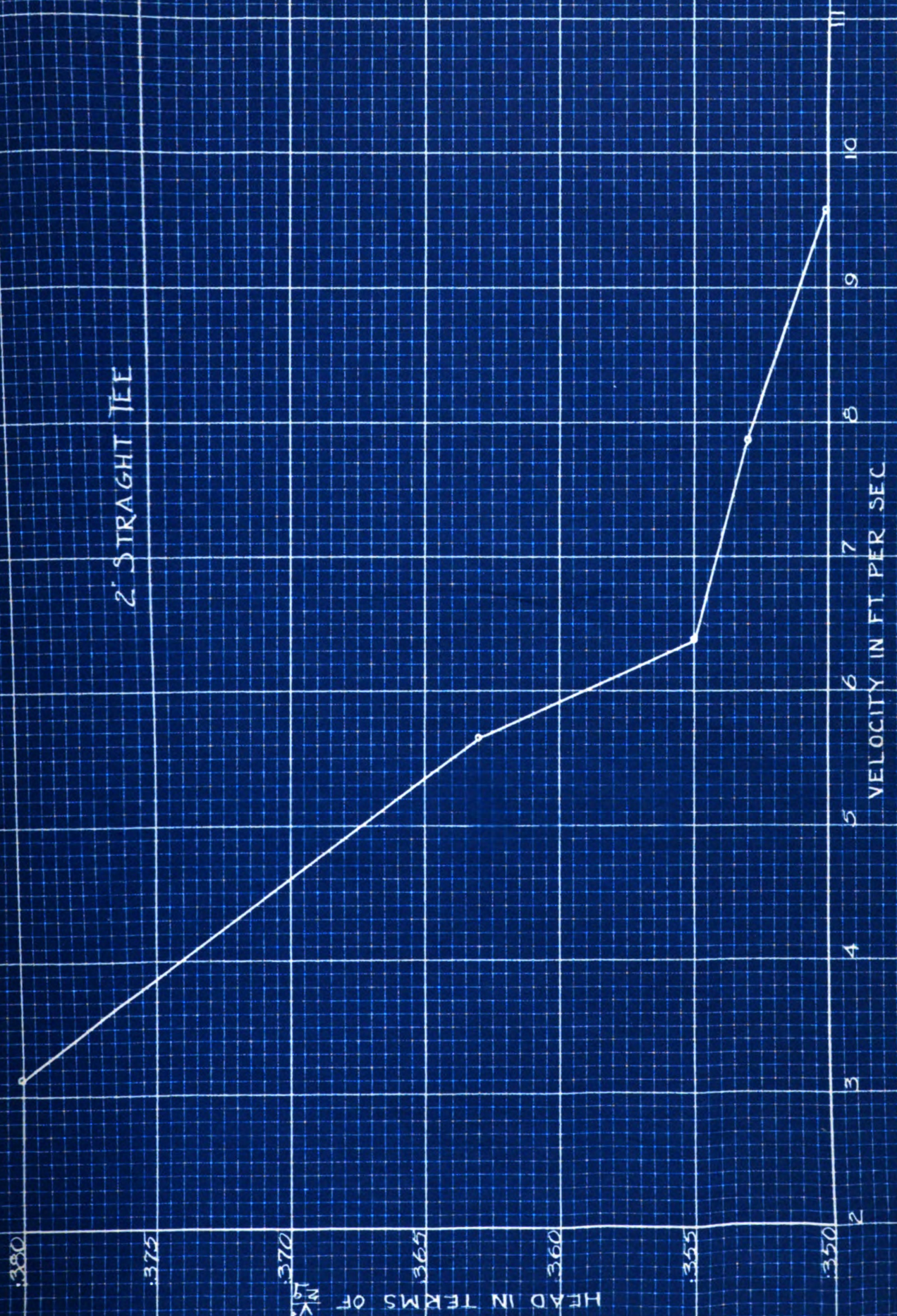


2" STRAIGHT TEE'S

Wgt. Water #	Time in Sec.	Head Loss in.Hg.	Head Loss ft.H ₂ O	Vel. in ft/sec.	$\frac{V^2}{2g}$	C.F.S.	Coef. per Fitt.
800	178.5	.24					
800	185.2	.22					
800	198.7	.20					
Aver.	187.5	.22	.251	3.13	.152	.0682	.580
800	118.9	.52					
800	96.2	.77					
800	96.2	.78					
Aver.	103.8	.69	.724	5.66	.497	.1235	.363
800	88.0	.90					
800	94.2	.84					
800	94.4	.83					
Aver.	92.2	.86	.904	6.37	.632	.129	.355
800	75.2	1.27					
800	75.0	1.28					
800	72.8	1.32					
Aver.	74.66	1.29	1.355	7.85	.957	.1715	.353
800	61.8	1.60					
800	61.0	2.00					
800	60.8	2.10					
Aver.	61.2	1.90	1.955	9.57	1.425	.209	.350

Final Average Loss per Fitting

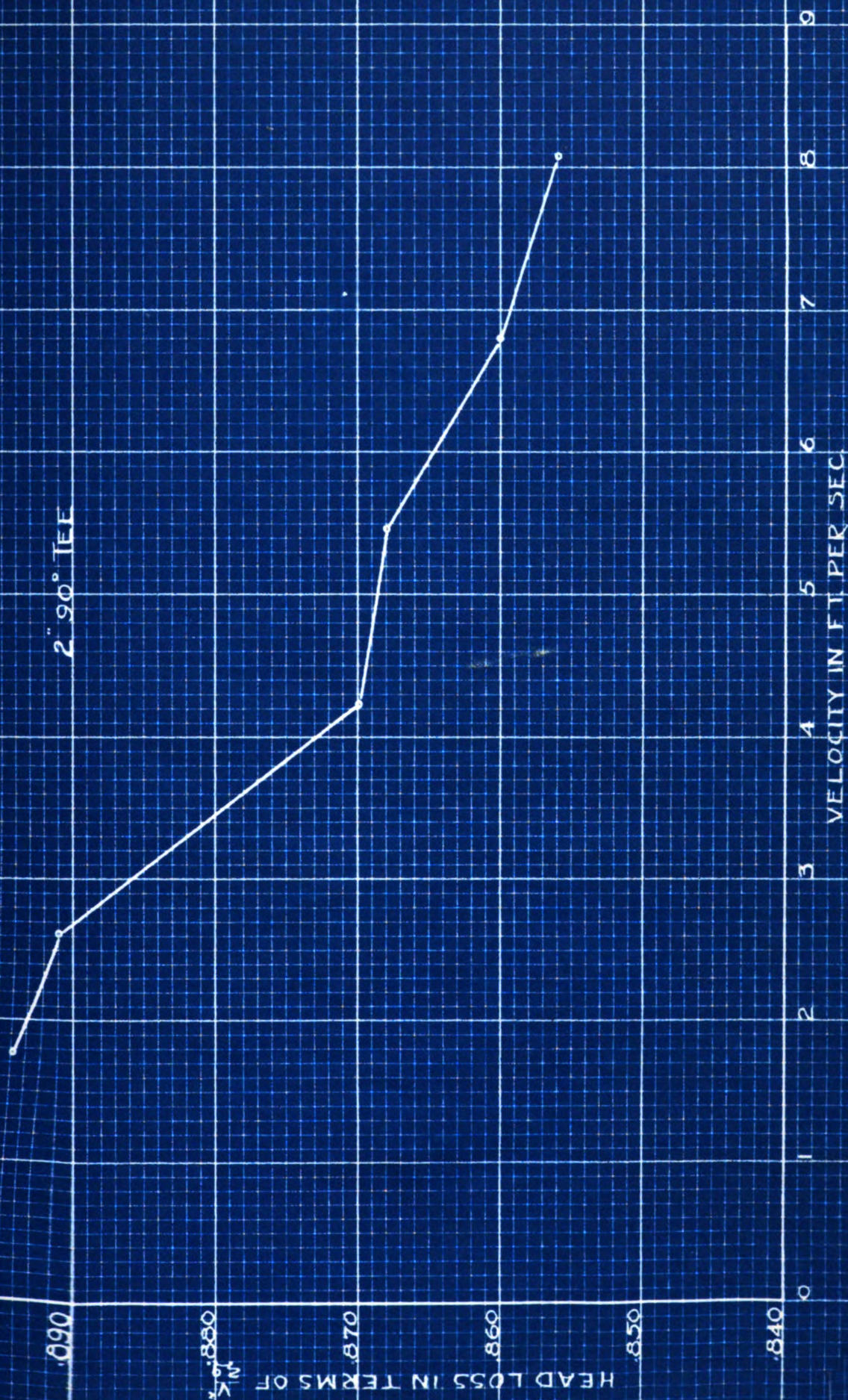
.360



10 (a)

2" 90° TLES

[illegible]



[illegible]

2" FLANGE

HEAD IN TERMS OF
IN.
19.25

19.75

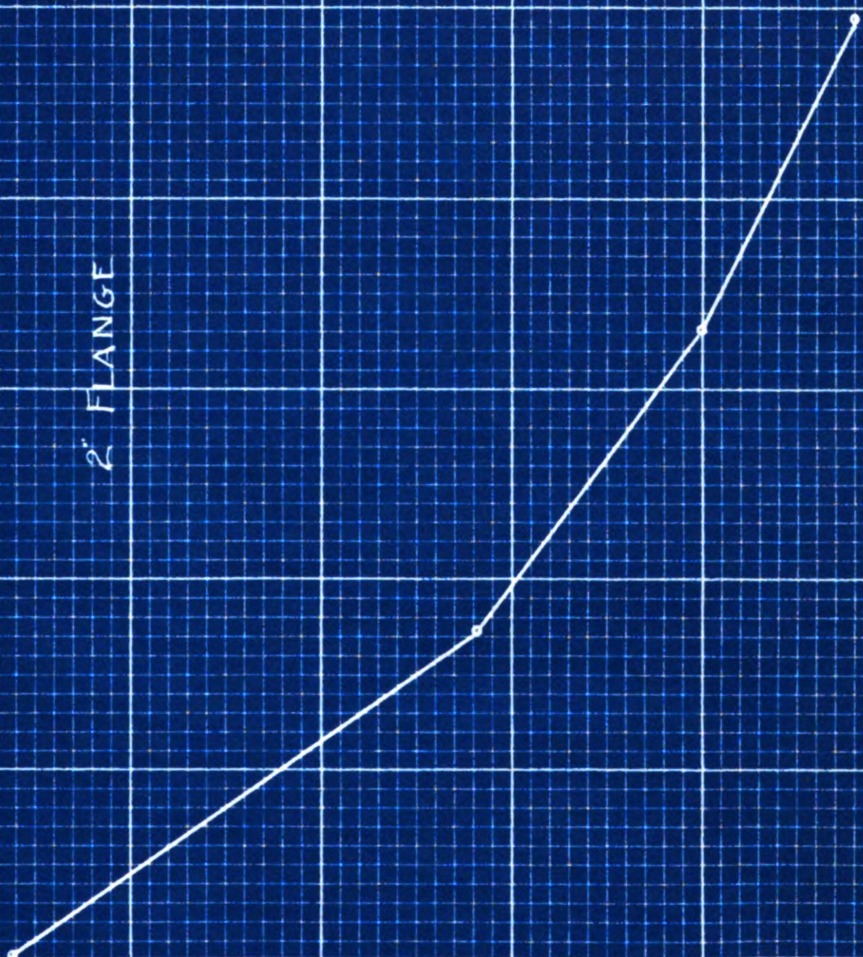
19.50

19.25

19.00

18.75

18.50



15(a)

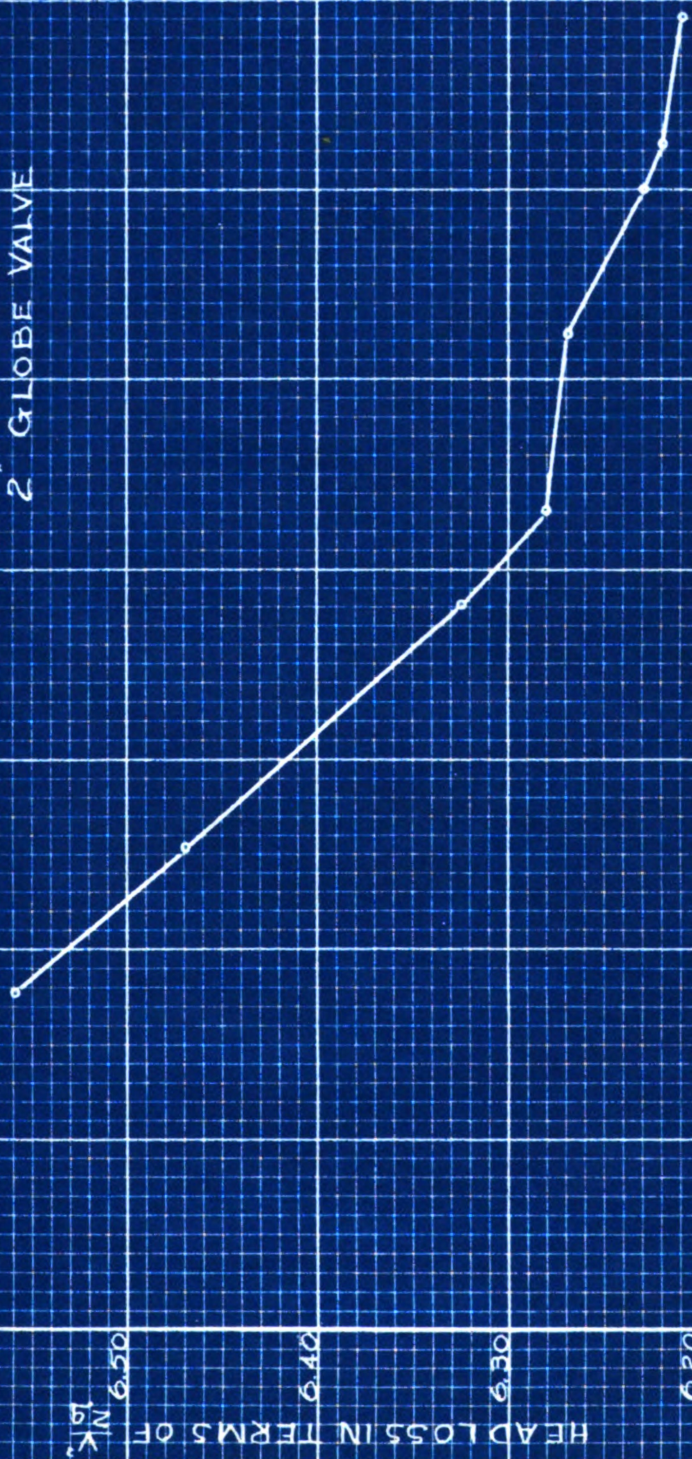
2" GLOBE VALVES

Wgt. Water #	Time in Sec.	Head Loss in.Hg	Head Loss ft.H2O	Vel. in ft/sec.	$\frac{V^2}{2g}$	C.F.S.	Coef. per Fitt.
800	236.0	1.18					
800	225.1	1.26					
800	229.0	1.24					
Aver.	230.0	1.226	1.288	1.78	.0491	.0288	6.56
800	232.0	2.40					
800	234.6	2.25					
800	225.1	2.24					
Aver.	232.9	2.40	2.418	2.51	.098	.0548	6.47
800	155.4	5.38					
800	154.4	5.41					
800	154.2	5.42					
Aver.	154.7	5.40	5.66	5.80	.224	.0828	6.525
800	125.2	6.96					
800	126.1	6.84					
800	127.8	6.77					
Aver.	126.4	6.86	7.21	4.30	.287	.0928	6.28
800	115.8	9.45					
800	112.4	10.06					
800	108.4	10.88					
Aver.	112.2	10.15	10.65	5.23	.425	.114	6.27

2" MICHAEL V. IVINS (CON.)

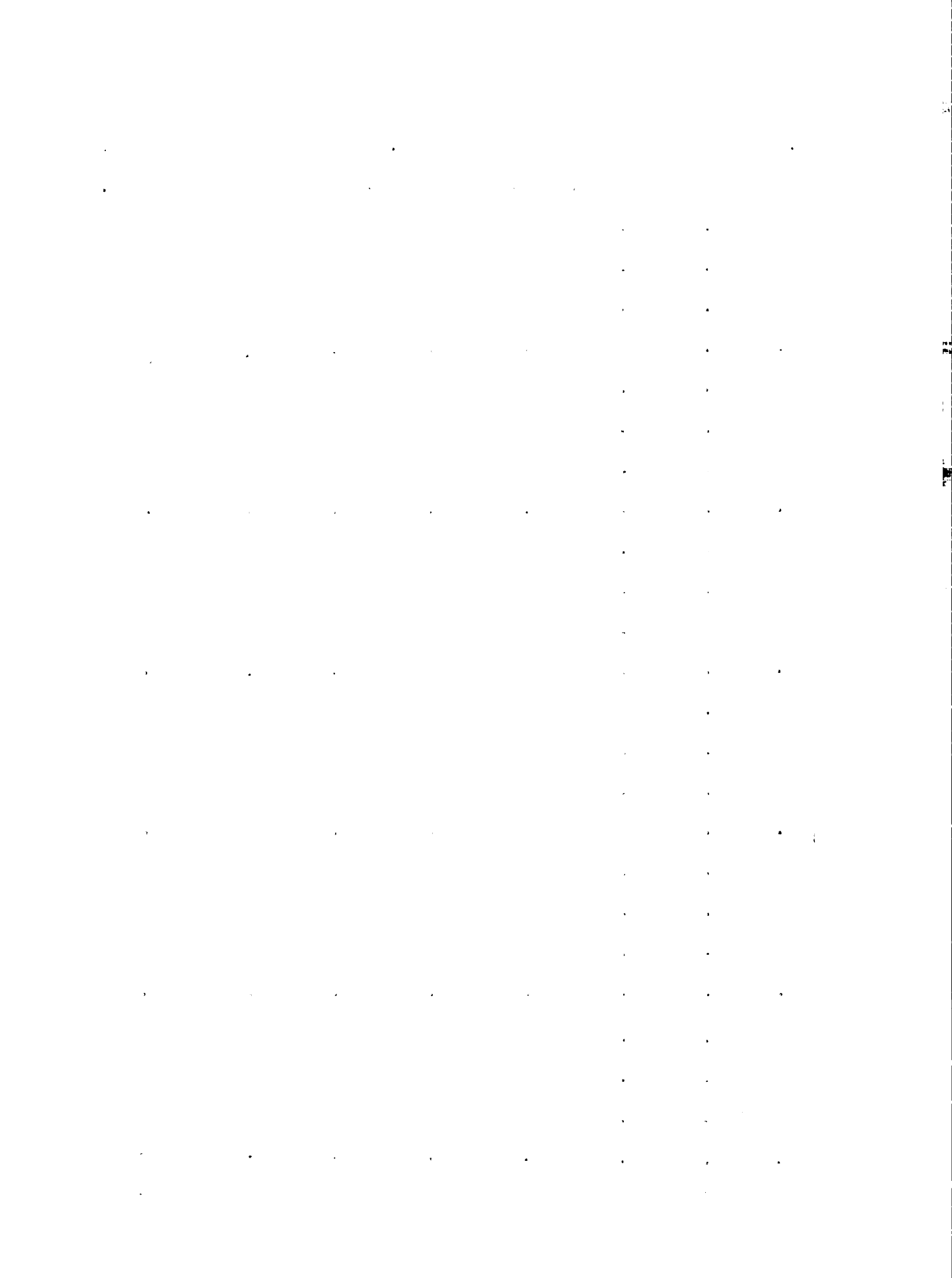
[illegible]

2" GLOBE VALVE



1" COUL-LINGS

[illegible]




$$z_2 > \sigma_1, 413$$

HEAD LOSS IN TERMS OF

415

414

413

412

411

410

409

408

407

406

405

$$15(\omega)$$

1" UNIONS

[illegible]

HEAD LOSS IN TERMS OF
 V^2
 UNIONS

VELOCITY IN FT. PER SEC.

.360

.350

.340

.330

.320

.310

6

10

14

18

22

26

30

100
100
100

100

100

100

100

100

100

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100

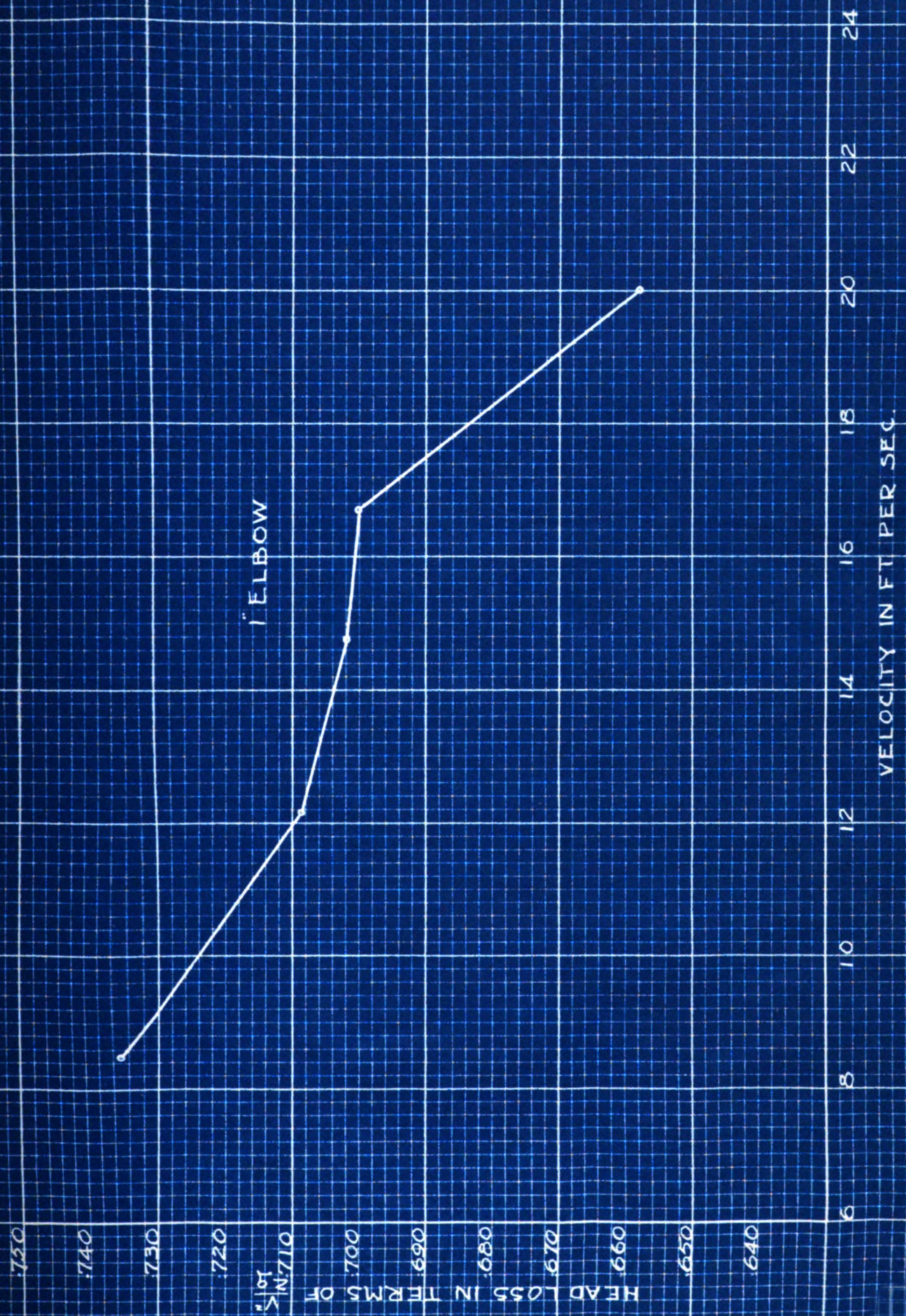
100

100

100

1" ELBOWS

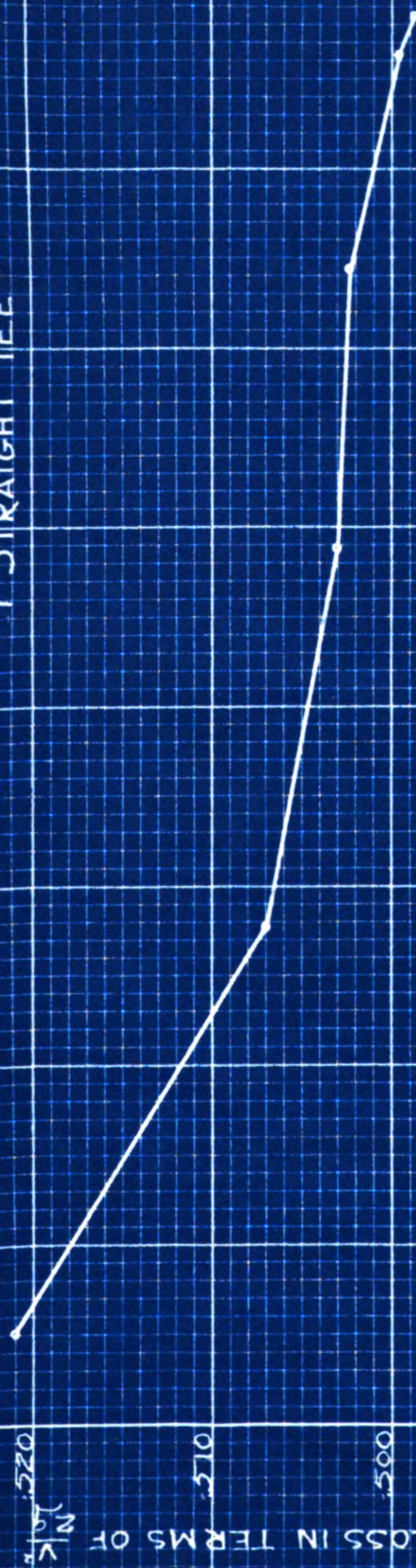
[illegible]



1" STRAIGHT TEES

[illegible]

1" STRAIGHT TEE

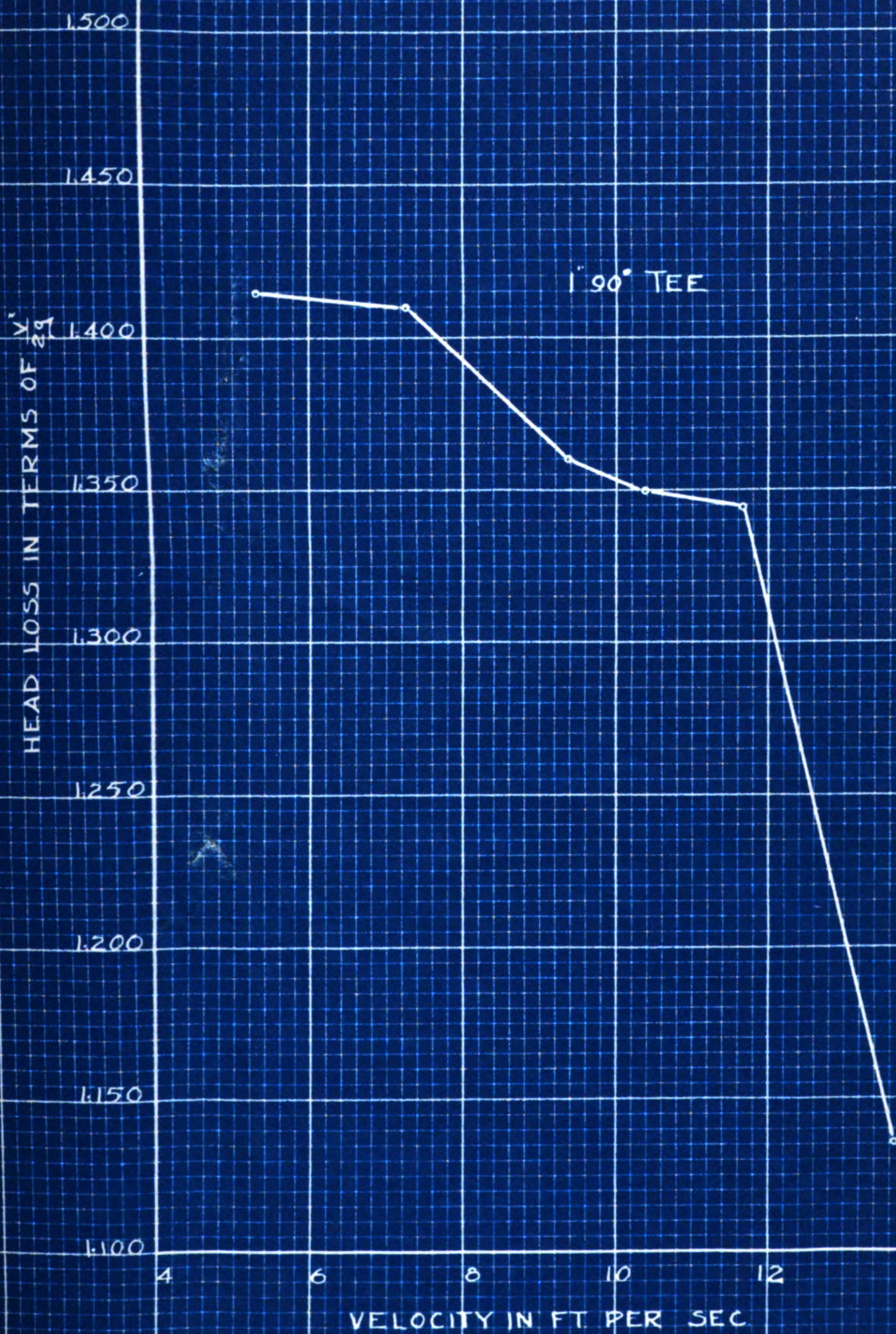


1" 90° TEES

Wgt. Water #	Time in Sec.	Head Loss in.Hg.	Head Loss ft.H ₂ O	Vel. in ft/sec.	$\frac{V^2}{2g}$	C.F.S.	Coef. per Fitt.
800	454.5	2.45					
800	429.3	2.41					
800	443.8	2.29					
Aver.	439.2	2.38	2.50	5.25	.444	.0291	1.415
800	509.5	4.70					
800	518.0	4.42					
800	550.0	4.22					
Aver.	519.2	4.445	4.57	7.29	.825	.0402	1.410
800	252.2	6.99					
800	250.3	7.01					
800	247.7	7.20					
Aver.	250.0	7.07	7.42	9.38	1.075	.0512	1.360
800	227.0	8.60					
800	229.0	8.51					
800	223.6	8.75					
Aver.	226.5	8.62	9.04	10.26	1.670	.0565	1.350
800	202.0	10.60					
800	202.9	10.63					
800	199.2	11.10					
Aver.	201.7	10.78	11.30	11.65	2.100	.0635	1.345
800	171.2	14.96					
800	171.2	14.94					
800	174.0	14.54					
Aver.	172.1	14.81	15.55	12.65	3.420	.0744	1.125

Final Average Loss per Fitting

1.380



2" CLUTLIN 03

[illegible]

100

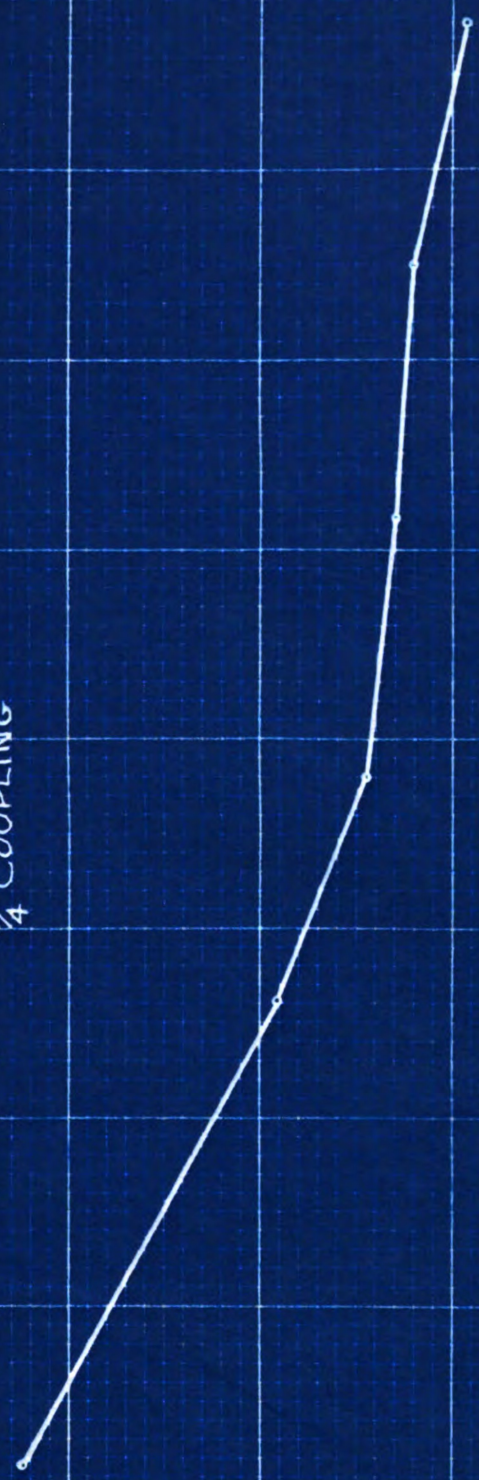
$\frac{3}{4}$ " COUPLING

HEAD LOSS IN TERMS OF $\frac{V^2}{2g}$

.2700
.2600
.2500
.2400
.2300

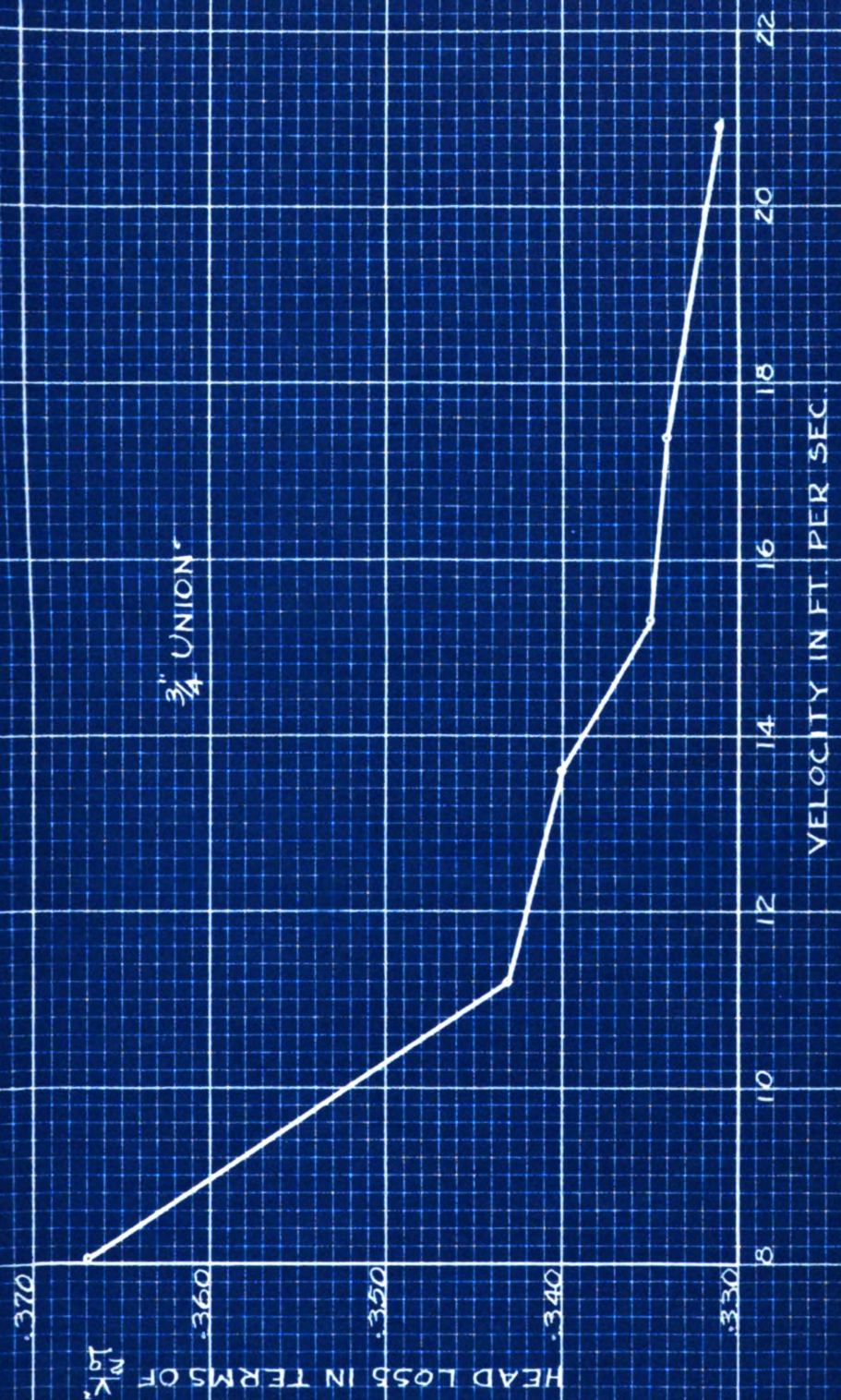
8 10 12 14 16 18 20 22 24

VELOCITY IN FT. PER SEC.



$\frac{3}{4}$ " UNIONS

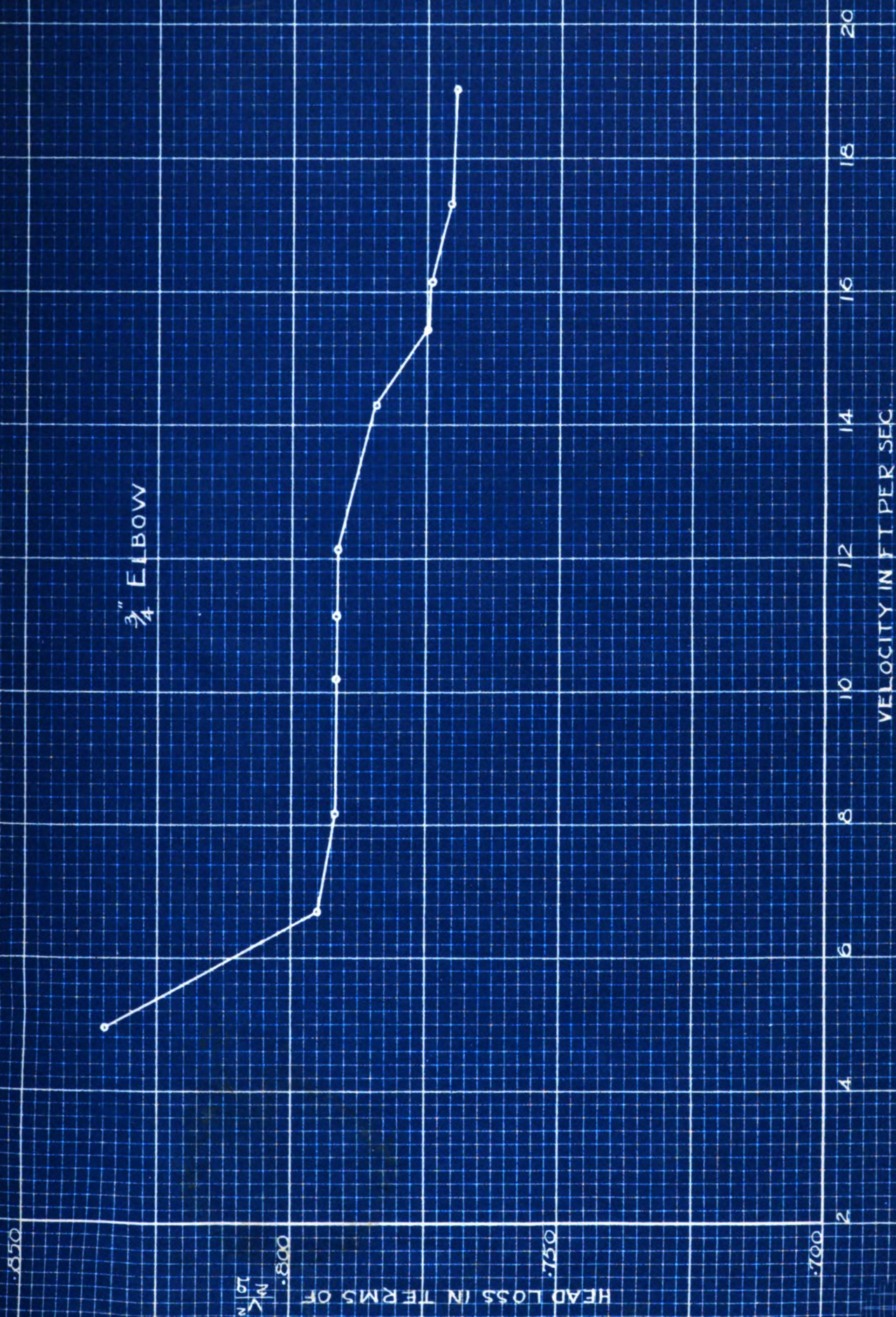
[illegible]



$\frac{3}{4}$ " ELBOWS

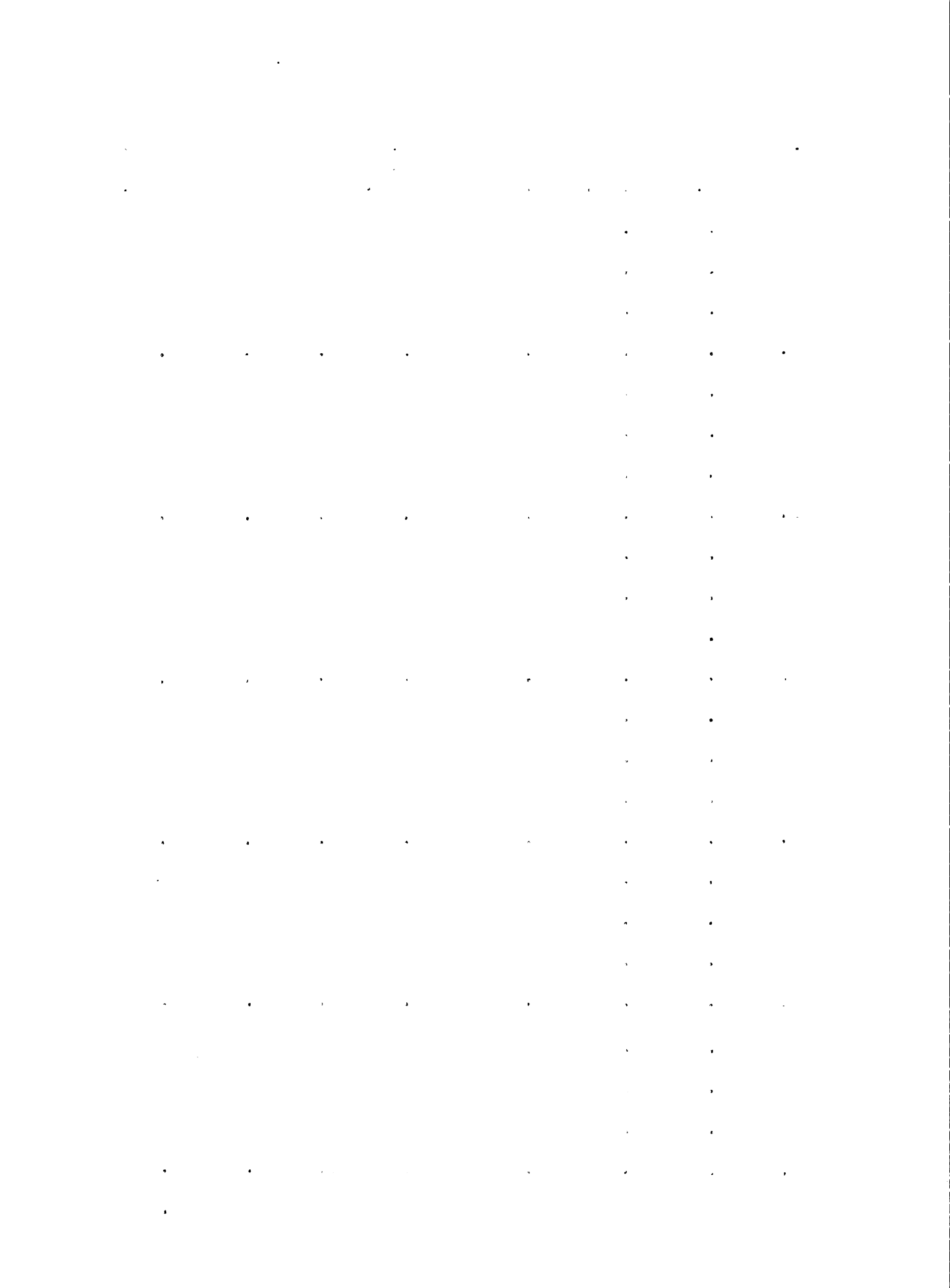
Wgt. Water #	Time in Sec.	Head Loss in.Hg.	Head Loss ft.H ₂ O	Vel. in ft/sec	$\frac{V^2}{2g}$	C.F.S.	Coef. per Fitt.
300	317.6	1.185					
300	317.6	1.193					
300	304.4	1.292					
Aver.	313.86	1.225	1.187	4.98	.6853	.0153	.824
300	230.0	2.16					
300	237.6	2.02					
300	232.4	2.15					
Aver.	233.3	2.11	2.22	6.70	.638	.0206	.795
300	190.4	3.17					
300	192.3	3.05					
300	191.3	3.12					
Aver.	191.2	3.11	3.37	8.17	1.027	.0251	.789
500	256.2	4.77					
500	255.4	4.87					
500	255.7	4.83					
Aver.	255.7	4.84	5.08	10.20	1.318	.0313	.788
500	234.0	5.75					
500	234.0	5.78					
500	234.2	5.79					
Aver	234.06	5.79	6.08	11.15	1.92	.0342	.788
500	210.6	7.10					
500	211.4	7.11					
500	221.2	6.48					
Aver.	214.4	6.896	7.24	12.15	2.495	.0373	.788

[illegible]

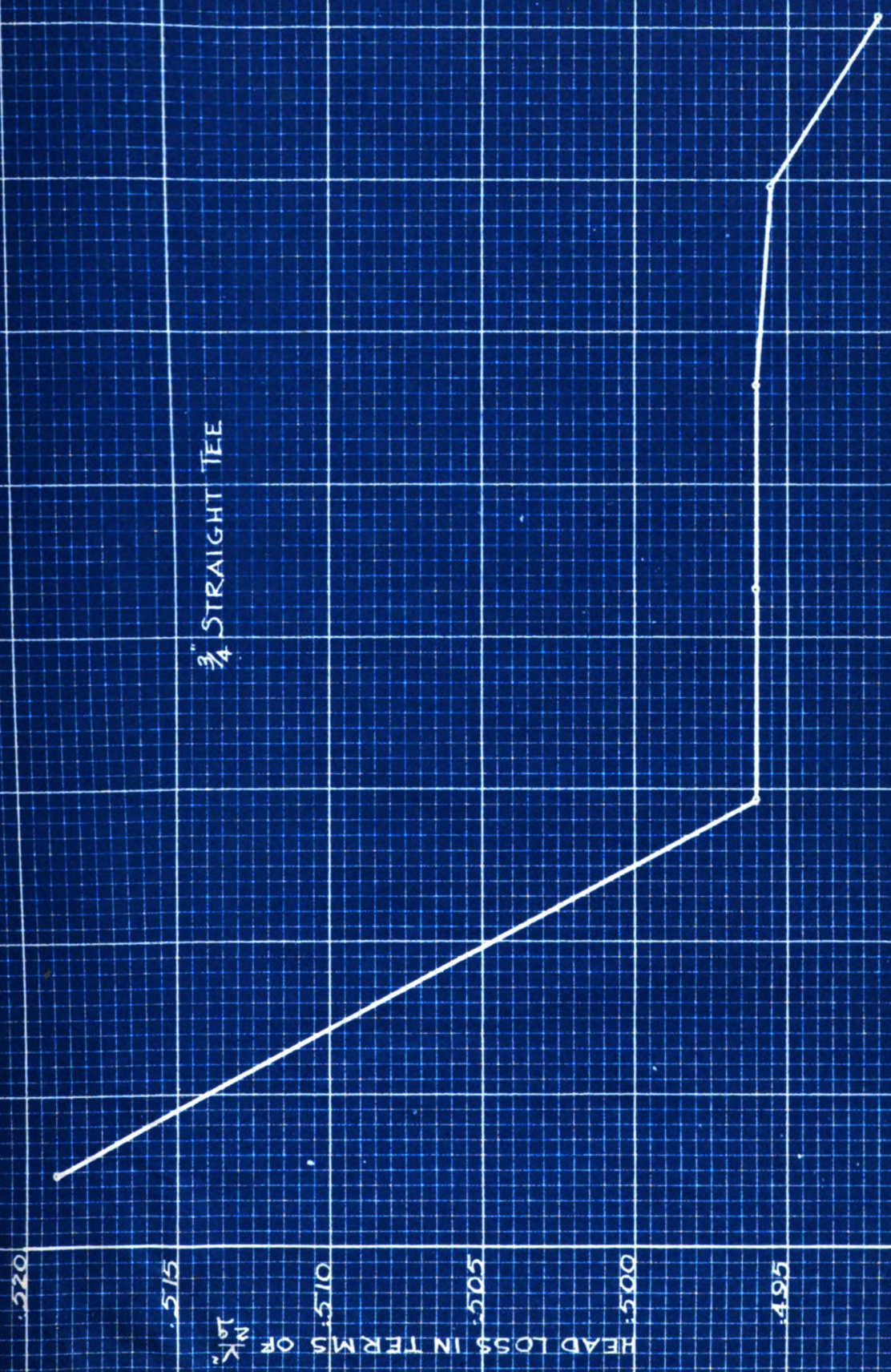


$\frac{3}{4}$ " STRAIGHT TEES

[illegible]



3/4" STRAIGHT TEE

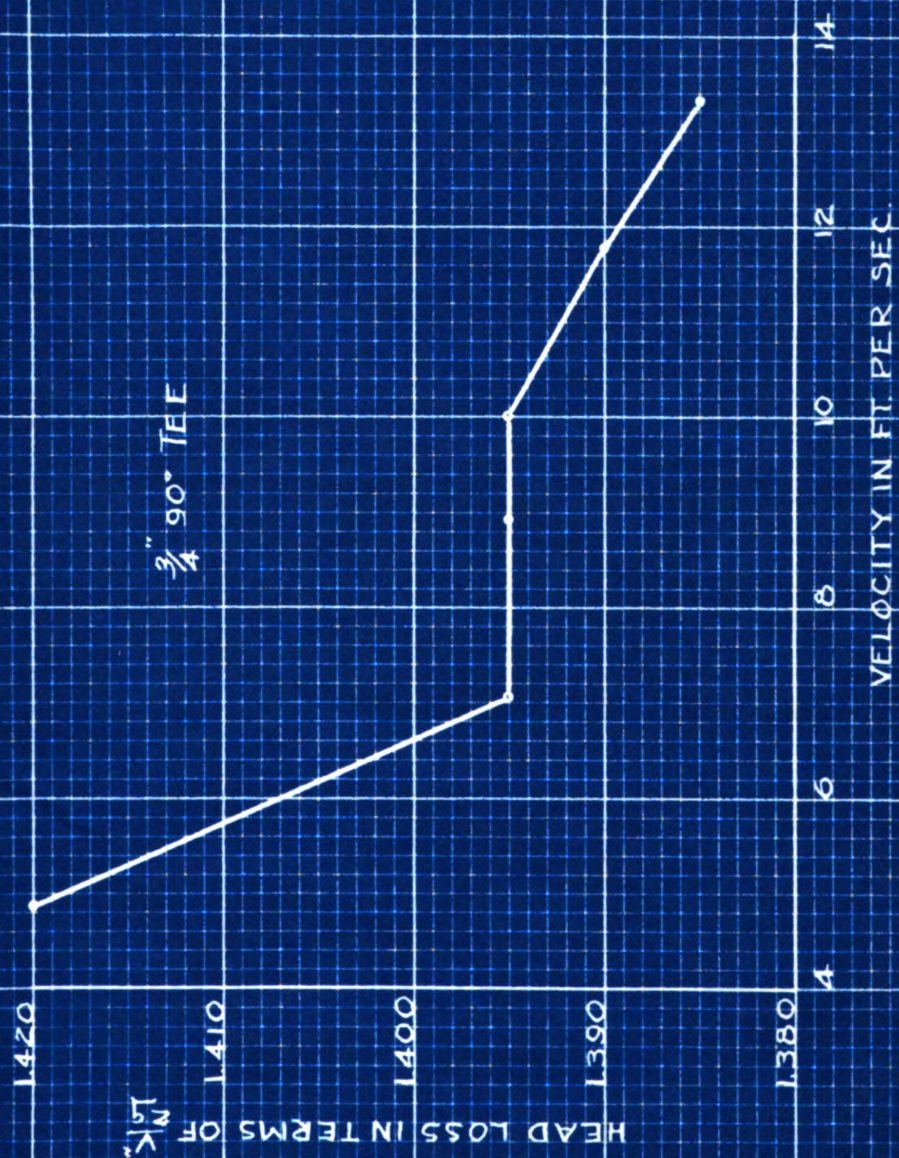


2" 90° TEES

Wgt. Water #	Time in Sec.	Head Loss in.Hg.	Head Loss ft.H2O	Vel. in ft/sec.	$\frac{V^2}{2g}$	C.F.S.	Coef. per Fitt.
300	213.0	2.04					
300	222.4	2.00					
300	223.2	1.85					
Aver.	223.5	1.96	2.06	4.84	.362	.0149	1.420
300	218.6	4.22					
300	221.4	4.20					
300	225.2	3.99					
Aver.	221.4	4.14	4.35	7.07	.778	.0217	1.395
300	177.0	6.49					
300	172.5	6.65					
300	175.7	6.60					
Aver.	175.1	6.58	6.90	8.92	1.225	.0294	1.395
500	261.4	8.23					
500	266.6	8.03					
500	256.1	8.52					
Aver.	261.4	8.26	8.67	10.00	1.555	.0307	1.395
500	229.0	10.56					
500	221.0	11.52					
500	212.5	12.34					
Aver.	220.8	11.48	12.05	11.80	2.165	.0362	1.390
500	196.0	14.50					
500	194.6	14.79					
500	196.1	14.45					
Aver.	195.6	14.58	15.31	13.32	2.760	.0409	1.393

Final Average Loss per Fitting

1.397

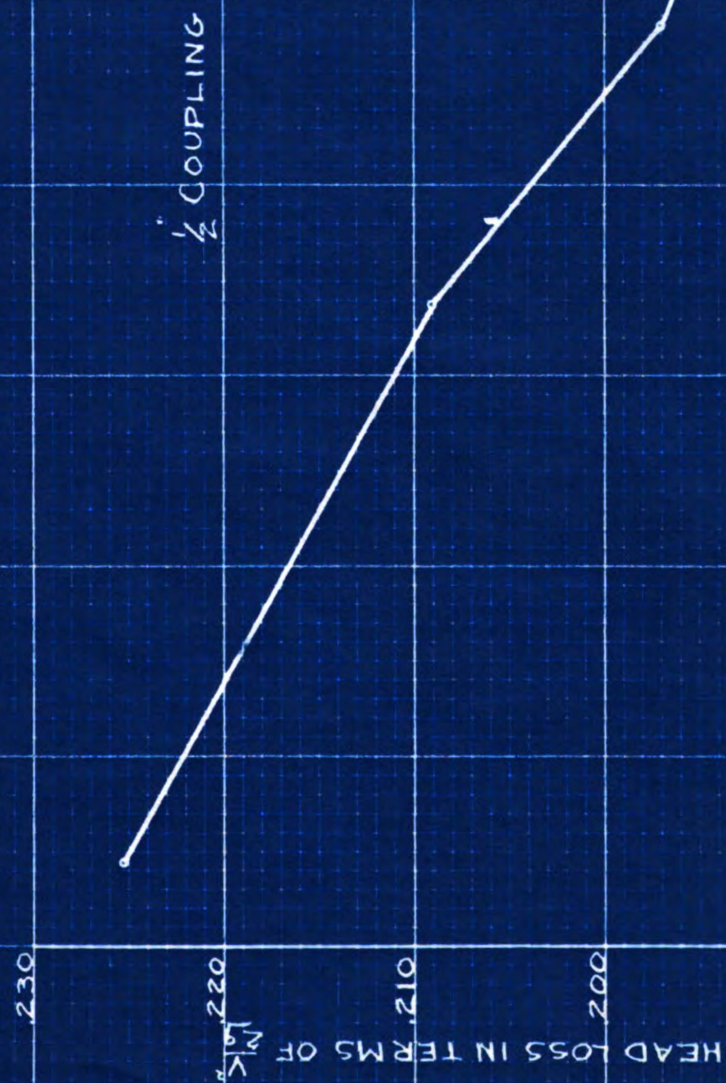


$\frac{1}{2}$ " COUPLINGS

Wgt. Water #	Time in Sec.	Head Loss in.Hg.	Head Loss ft.H ₂ O	Vel. in ft./sec.	$\frac{V^2}{2g}$	C.F.S.	Coef. per Fitt.
200	395.5	0.53	.				
200	400.6	0.50					
200	393.5	0.52					
Aver.	396.2	0.52	0.546	5.90	.541	.0081	.252
200	202.0	1.30					
200	196.0	1.39					
200	198.2	1.35					
Aver.	199.1	1.35	1.720	11.78	2.135	.0161	.209
200	163.0	2.47					
200	157.8	2.53					
200	159.0	2.54					
Aver.	159.6	2.53	2.650	14.70	3.260	.0207	.197
200	138.6	3.20					
200	133.2	3.55					
200	132.2	3.57					
Aver.	134.7	3.47	3.620	17.45	4.725	.0238	.192
300	178.0	4.44					
300	176.4	4.49					
300	175.3	4.54					
Aver.	176.6	4.49	4.720	19.92	6.175	.0372	.191
300	159.8	5.45					
300	161.1	5.39					
300	152.7	5.85					
Aver.	157.8	5.56	5.840	22.30	7.725	.0304	.189

Final Average Loss per Fitting

.205

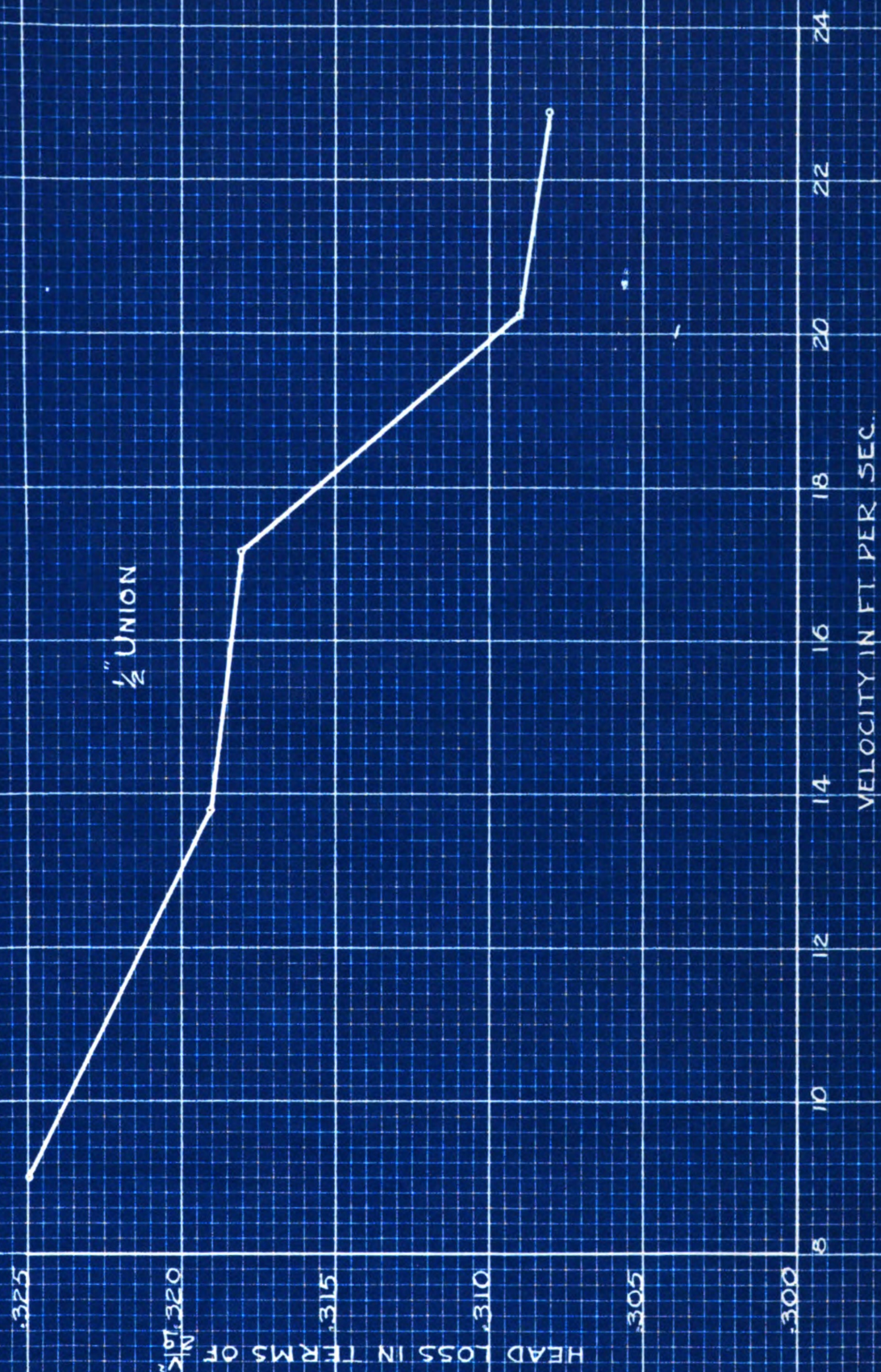


$\frac{1}{2}$ " UNIONS

Wgt. Water lb	Time in Sec.	Head Loss in.Hg.	Head Loss ft.H ₂ O	Vel. in ft/sec.	$\frac{V^2}{8g}$	C.F.S.	Coef. per Fitt.
200	264.1	1.50					
200	254.6	1.61					
200	250.2	1.64					
Aver.	256.3	1.56	1.64	9.00	1.26	.0125	.325
200	170.2	3.56					
200	168.7	3.67					
200	169.5	3.57					
Aver.	169.5	3.57	3.75	13.79	2.95	.0189	.319
300	203.0	5.54					
300	202.5	5.50					
300	202.2	5.58					
Aver.	202.7	5.54	5.82	17.15	4.57	.0237	.318
300	170.7	7.74					
300	175.2	7.30					
300	174.2	7.45					
Aver.	173.4	7.50	7.88	20.25	6.38	.0277	.309
500	255.4	9.61					
500	257.8	9.34					
500	255.0	9.73					
Aver.	256.1	9.56	10.05	22.90	8.15	.0313	.308

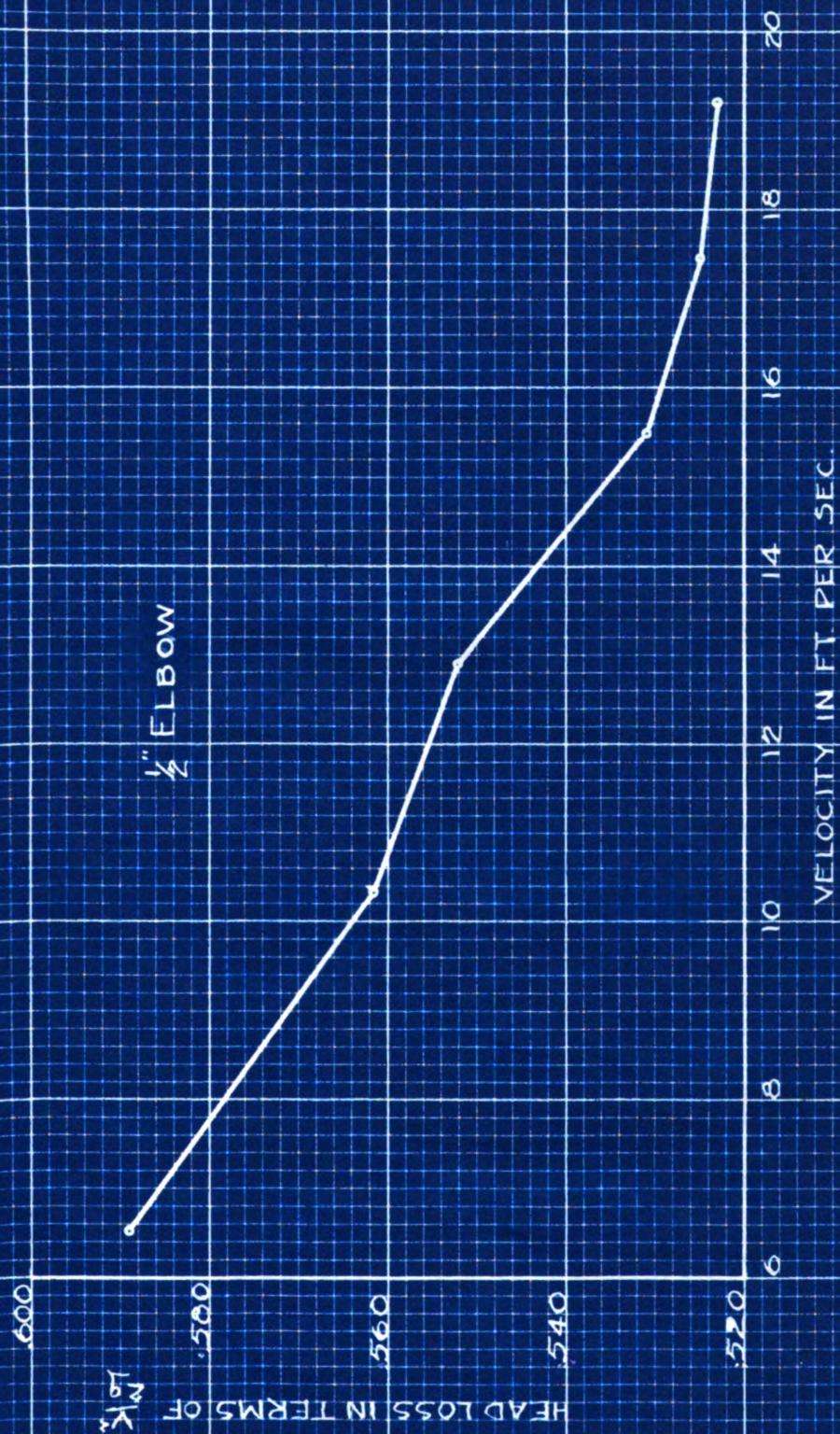
Final Average Loss per Fitting

.313



$\frac{1}{2}$ " ALBON 3

[illegible]



$$f(z)$$

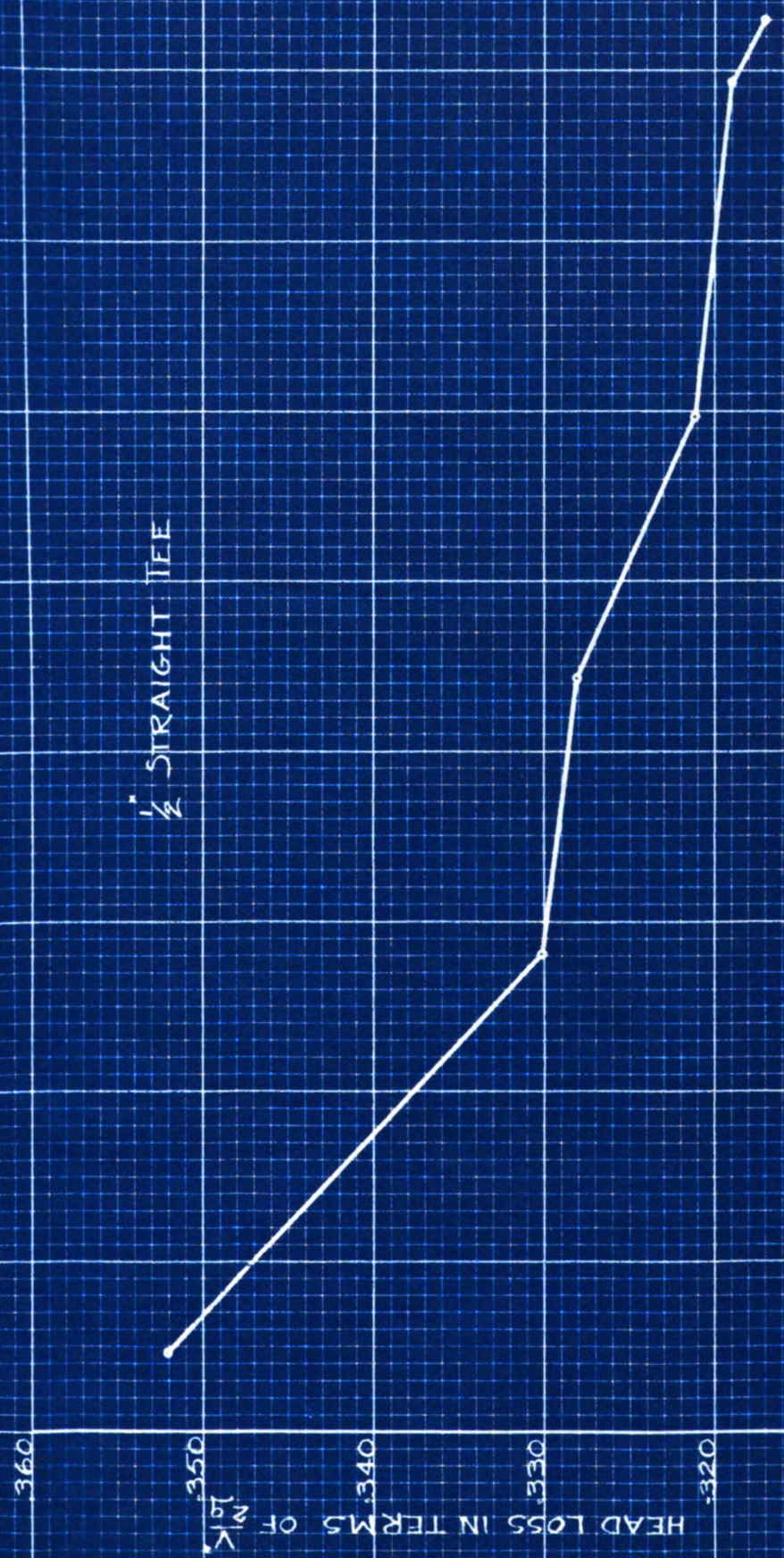
$\frac{1}{2}$ " STRAIGHT REELS

[illegible]

Final Average Loss per Fitting

.328

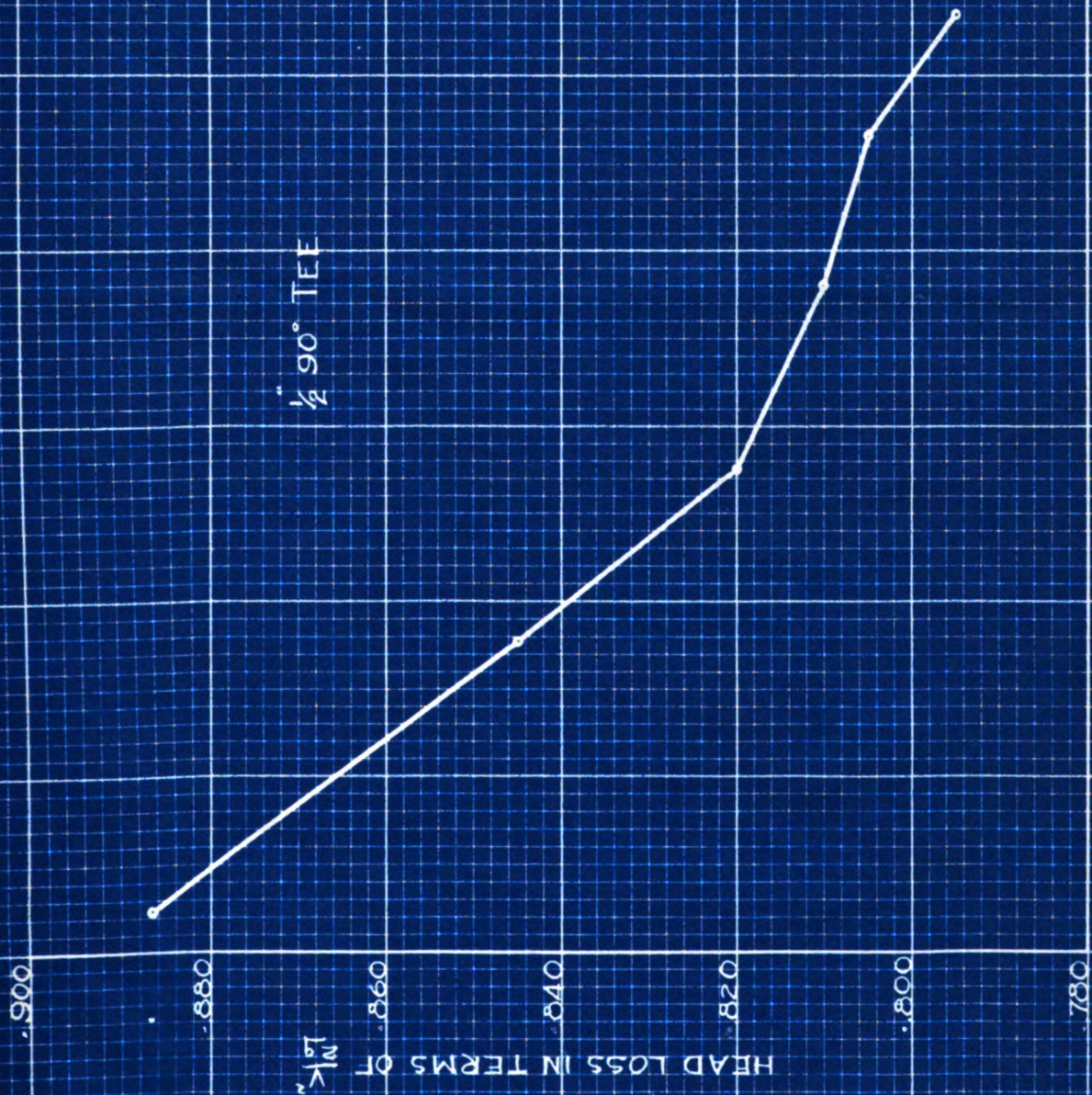
1/2 STRAIGHT TEE



29 (a)

$\frac{1}{2}''$ 90° TAPS

[illegible]

$\frac{1}{2}$ 90° TEE

CONCLUSION

After looking over the results we came to the following conclusion: that as the velocity increases the coefficient of head loss decreases. In general our curves show that a definite dropping off of the coefficient takes place between the velocities of 3 to 6 ft. per second. After this drop, it levels off or slopes gradually to about a velocity of 18 ft./sec. and then drops off again slightly.. As there were not enough points on most of our curves to definitely be sure of the above statement we took an extra number of different velocities on our test of the $\frac{3}{4}$ inch elbows. This test seemed to support our theory. The graph of the test for the $\frac{3}{4}$ inch elbows may be found on pages 20(b) and 21(b).

There were undoubtedly some sources of error in our experimental work, but, due to lack of time and proper equipment, we were unable to eliminate these. In all cases, the ends of the tubes that connected the pipe line to the manometer hose, extended down into the pipe line a little bit. This would cause a slight error, but as both of these tubes were alike in this respect the error would be partially eliminated. Another factor of error was in the reading of the manometer. At the higher velocities, the pressure was very unsteady and this tended to make the mercury col-

umn move with such rapidity as make taking an average reading very difficult. In all cases a number of readings were taken during each trial and their average was used in the computations. Although we tried to get all of the pipe fittings of the same quality, as far as roughness of the interior was concerned we had no way of ascertaining the extent of this factor. This may have given a higher frictional resistance to some fittings than to others.

In conclusion we wish to express our belief that the results herein presented are of sufficient accuracy to be used in the computation of the head loss through a working pipe system. We hope that in the future some graduating student will be interested enough in this subject to go into it in more detail, using our work as a basis for his thesis.

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