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# Fluid Friction Losses in Two Sets of Black Steel Pipe of Recent Manufacture

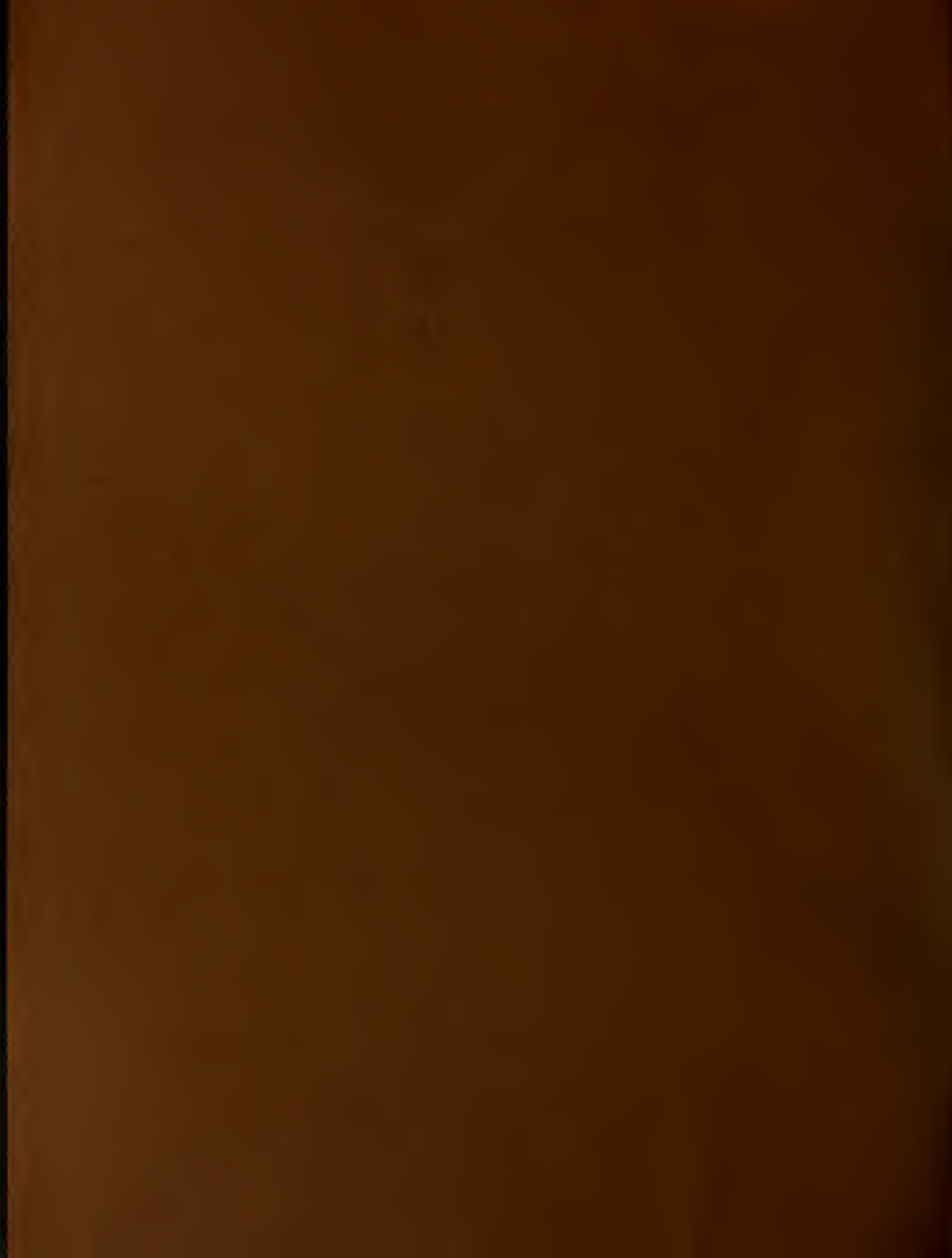
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Technical Summary  
Fluid Friction Losses in  
Black Steel Pipe

See Text

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**FLUID FRICTION LOSSES IN TWO  
SETS OF BLACK STEEL PIPE OF  
RECENT MANUFACTURE**

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May 1980

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# Fluid Friction Losses in Two Sets of Black Steel Pipe of Recent Manufacture

by

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## Abstract

Two sets of black steel pipes have been flow-tested at the National Bureau of Standards (NBS) to determine their fluid frictional loss characteristics. Twenty foot lengths of pipe furnished by the American Iron and Steel Institute ranging from one to three inches nominal pipe size were tested using water in the primary flow measurement facilities at NBS. These facilities use static gravimetric techniques with precision timing to determine flow rates to within  $\pm 0.13\%$  based upon three standard deviations. Pipe pressure losses were measured using water and mercury manometers for pipe flow velocities ranging from 4 to 16 feet per second. Frictional loss characteristics of each pipe are characterized using the conventional Hazen-Williams formulation at each flowrate.

## Introduction

The basic equation relating fluid head loss or pressure loss to frictional loss in long straight tubes or pipes is the Darcy equation,

$$h_L = f(L/D)(V^2/2g) \quad [1]$$

The loss in pressure or hydrostatic head  $h_L$  is proportional to the velocity head,  $V^2/2g$ , the length,  $L$ , and diameter,  $D$ , of the pipe in compatible units. The dimensionless quantity,  $f$ , is known as the friction factor and has been shown to depend on the pipe roughness and diameter and the average velocity,  $V$ , of flowing fluid. Experimental studies by Nikuradse [2], Colebrook [3] and Moody [4] have shown that the friction factor is a function of the Reynolds number and can be related quantitatively to the physical height of the surface topography of the pipewall, i.e., the roughness height non-dimensionalized by the pipe diameter.

Empirical relations have been derived from experimental test data for water flowing in pipes under turbulent conditions. One of the more widely used in the U.S. is that of Hazen and Williams [5] which relates the average velocity,  $V$ , the hydraulic radius  $R$ , and the head loss per unit length,  $S$ .

$$V = 1.318 C R^{0.63} S^{0.54} \quad [2]$$

where  $S = h/L$

$C$  = Hazen-Williams coefficient

$L$  = length of pipe over which the head loss occurs

$h$  = head loss in feet of the flowing fluid

Substitution of the hydraulic radius for a pipe of circular cross-section ( $D$  = diameter in feet) into this relation yields

$$v = 1.318 \left(\frac{D}{4}\right)^{0.63} \left(\frac{h}{L}\right)^{0.54}$$

Inclusion of the kinematic viscosity,  $\nu$ , and the Reynolds number,  $R_E$ , yields

$$h = \frac{194 D^{-0.015}}{C^{1.85} \nu^{0.15} R_E^{0.15}} \left[\left(\frac{L}{D}\right) \left(\frac{v^2}{2g}\right)\right] \quad [3]$$

This relation has the form of the Darcy equation with the friction factor given in terms of the Hazen-Williams coefficient.

$$f = \frac{194 D^{-0.015}}{C^{1.85} \nu^{0.15} R_E^{0.15}} \quad [4]$$

Neglecting the term  $D^{-0.015}$ , i.e., assuming that its value is nearly unity, it is evident that the friction factor is dependent only upon the Reynolds number and Hazen-Williams coefficient for fluids whose kinematic viscosity exhibits small changes over the region of interest.

#### Computation of Hazen-Williams Coefficient Values

The Hazen-Williams coefficient may be expressed in the following form for the purpose of computation from the experimentally determined values and reported here.

$$C = Q [4.52 L/PD^{4.87}]^{0.54} \quad [5]$$

where  $Q$  = flowrate gallons/minute (gpm)  
 $P$  = pressure drop pounds/in<sup>2</sup> (psi)  
 $L$  = distance over which the pressure drop occurs (ft)  
 $D$  = internal pipe diameter (in).

In this form only dimensional parameters are required to relate the pressure loss in the pipe to the flowrate which is generally of primary interest.

Presently accepted values for the Hazen-Williams coefficient are based on data that was taken on steel pipe manufactured in a manner which may have produced a higher degree of roughness of the wall than is thought to be the case for steel pipe manufactured using more modern methods. In order to test the effect of these newer manufacturing techniques

the American Iron and Steel Institute (AISI) has sponsored a set of tests conducted in the primary flowmetering facilities of the National Bureau of Standards (NBS). This test procedure has been performed with two sets of five black steel pipes having nominal diameters ranging from one to three inches and lengths of twenty feet.

#### Visual Inspection and Dimensional Measurements

Each pipe length was received at NBS with pressure taps installed as per recommendation of the American Society of Mechanical Engineers (ASME) and placed ten pipe diameters from either end. Each tap was a circular hole approximately one-eighth inch in diameter with a threaded fitting welded to it so as to provide connection to the appropriate pressure measurement device. These holes were inspected visually for smoothness on the inside pipe wall. No obvious burrs or other irregularities around the holes were detected. Such burrs or irregularities can cause pressure drops associated with the holes themselves thereby introducing pressure losses higher than those which actually occur along nonperforated pipewalls.

Dimensional measurements were made at NBS to determine the characteristic lengths of the pipe sections. The results of measurements of the internal diameters and distances between the pressure taps for each pipe are given below.

Table 1

<u>Pipe No.</u>	<u>Internal Diameter (inches)</u>	<u>Standard Deviation (inches)</u>	<u>Pressure Tap Separation (feet)</u>
1A	1.0557	0.0032	18.86
1B	1.0659	0.0022	18.36
1.25A	1.3813	0.0017	17.83
1.25B	1.3892	0.0029	17.57
1.5B	1.6238	0.0045	17.18
2A	2.0665	0.0050	16.39
2B	2.0919	0.0033	16.12
2.5A	2.4740	0.0030	15.55
3A	3.0738	0.0068	14.47
3B	3.0994	0.0040	13.63

The internal diameter of each pipe was measured at either end well inside the slight taper located in the threaded end of the pipe. Several observations were made on each pipe, involving a change in position of the internal micrometer such that the micrometer lands contacted different portions of the wall with each measurement. The value given above is the average of the observed diameters taken at both ends of each pipe. The variation in the diameter is indicated by the standard deviation of the mean value. The accuracy of the micrometer measurements was 0.0005 inches over the diameter range as determined by repetitious observations on master setting rings. The distance between the pressure taps was measured using a tape measure. This measurement was made between the centerlines of the holes constituting the pressure taps. The uncertainty of these measurements is approximately 0.06 inches, the primary component

of error being in the determination of the end points and in the nonreproducibility of the catenary of the tape.

### Test Set-Up

Each pipe was tested by placing it in the test section of the NBS primary water flow measurement facilities. Measurement of the water flow rate through the pipe under test was determined by the gravimetric technique. This technique of flowrate measurement requires measurement of the mass of flowing liquid, in this case water, passing through the pipe or flow measurement device over a measured period of time. The density of the liquid must also be known or inferred from a measured temperature. In this case, the temperature of the water is measured in the pipeline and a value for the corresponding density is obtained from tabulated values [6]. The flowrate measurement process involves diversion of the flowing liquid into a weigh tank for the measured amount of time and then diverted back into the sump of the flow loop. The water is weighed and the mass flowrate is determined. Volumetric flowrate is then obtained by division of the mass flowrate value by the density value inferred from the temperature value. The uncertainty of the flowrate values is 0.13% (3 standard deviations) for the facilities used in this test. For the time period of the flowrate measurement the response of the device under test is observed, i.e., the pressure drop in the pipe is measured and an average value determined.

A complete test was comprised of pressure response measurements made at five flowrate values distributed over the desired range. At each flowrate setting, five sets of observations were made. Generally, observations at the five flowrates were made on one day and were repeated on the following day. For all pipes except the two smallest sizes this schedule was followed. At the two smallest sizes, all of the observations were made on the same day although the measurement was shutdown after the first series of five measurement and then restarted after an hour or two.

The fluid velocity range for these tests was 4 to 16 feet/second. In most cases, however, the lower flowrate was approximately 5 feet/second. These values correspond to approximately 25 to 300 gallons/minute for these pipes.

The initial setup procedures were done using pipe number 3A. This pipe was run for several days to shake down the system. This pipe was subjected to the corroding influence of water for a significantly longer period of time than the other test specimens. The measurement results reported for 3A reflect this fact.

Pressure difference measurements were made using either water or mercury manometers connected across the pressure taps of the pipe. The range of the water manometer used is sixty inches corresponding to a pressure differential of approximately 1450 pascals (Pa) or 2.1 pounds/inch<sup>2</sup> (psi). For pressures above approximately 2.0 pounds/inch<sup>2</sup>, a mercury manometer was used. Observations of the manometer height were made throughout the time of each flowrate measurement. From 4 to 20 values were observed visually over the measurement times and the mean value and standard deviation was calculated.



## Results

The Hazen-Williams coefficient were calculated using [5] with the observed flowrates, pressure differentials, lengths and diameters. Values for the results and measured parameters are listed in Appendix I for each run. Mean values of the test results for each pipe are given in Table 2 for each pipe. Friction factors have been computed using the approximate form of equation 4, i.e., assuming  $D^{-0.015}$  is unity. Figures 1 through 4 are plots of the data.

Figure 1 shows the variation of the Hazen-Williams coefficient with flow rate for the one inch and for the one and one-quarter inch pipes. The dependence of the coefficient on flowrate is small in both cases and the reproducibility less than 1%. In the next pipe size, Figure 2, only one test specimen was supplied, i.e., 1.5 in. The data exhibits a higher degree of scatter than that found for the smaller pipe sizes, i.e., approximately 2%, and is only slightly dependent on flowrate over this range.

Figure 3 shows that for the two inch size, a different situation has occurred. The data shows an offset of one and one-half to three percent between the runs from different days. The offset is essentially constant, reproducing the shape of the curve characteristic of the previous day's data. Pipe 2A shows a significant downward shift of the coefficient between the first and second set of observations. Pipe 2B shows a similar shift but of smaller and more constant magnitude. The shape of the response of the 2A indicates a continuous decrease in the Hazen-Williams coefficient. This behavior may be explained by the continuous corrosion of the pipewall by the water causing a steadily increasing wall roughness and concomitant increase in frictional factor. For both of the two inch diameter pipes the upper set of points (higher values of Hazen-Williams coefficient) represent the first days results after which the pipes were left in a filled condition overnight in the case of 2B or over a weekend for 2A. It would appear that the longer delay in the case of 2A deteriorated the walls to a greater degree increasing frictional losses. Only one pipe at the two and one-half inch size was tested. The results are plotted in figure 4. The upper set of points are the first day's results. This pipe was removed from the test section rinsed with alcohol, and a rag pulled through it to dry the pipewalls. A week later it was installed in the test section again and the second set of runs were made; the results are the lower set of points. The results of the test on the pipe 3B are similar (see Fig. 4) to those of 2.5A although the coefficient values are higher and show a somewhat stronger dependence on flowrate. This pipe was treated similarly to 2.5A in the removal and drying procedure and was tested again about one week later. As discussed earlier pipe 3A was used for a more extensive length of time and at higher flowrates than the other pipes. The results listed in table 2 were derived from data taken after two or three days of shakedown testing during which the level of corrosion of the pipewalls would be expected to be greater than with those subjected to water for a shorter period of time. It should be noted that the water used for this testing was highly aerated by the pumps and diversion procedure, thereby providing the essential ingredients corroding these pipes. Visual observation of the amount of rust present in each of the pipes after completion of the tests show similar levels of corrosion in all pipes except 3A which appeared to have rusted to a higher degree.

Table 2

## Mean Values of Test Results

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1A

DATE JAN 9 80 OBSERVERS - JM PB

AVE. INNER DIA. - 1.0557 INCHES; TAP SEPARATION - 18.959 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	15.4	0.04	0.990	.0046	148.32	0.05	5.64	0.0207	50866
2	20.1	0.07	1.597	.0101	149.30	0.12	7.35	0.0197	66647
3	23.5	0.01	2.107	.0117	150.52	0.42	8.61	0.0189	78319
4	28.0	0.01	2.900	.0030	150.99	0.06	10.27	0.0183	93371
5	31.7	0.03	3.656	.0109	150.91	0.13	11.63	0.0180	105777
6	31.7	0.03	3.655	.0064	150.95	0.08	11.62	0.0180	106598
7	28.0	0.01	2.900	.0031	150.82	0.11	10.25	0.0184	94053
8	23.4	0.02	2.098	.0030	150.12	0.04	8.57	0.0190	78488
9	20.1	0.10	1.600	.0023	149.79	0.72	7.39	0.0196	67408
10	15.6	0.01	1.020	.0021	148.37	0.12	5.73	0.0207	52472

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1B

DATE JAN 9 80 OBSERVERS - MH &amp; JM

AVE. INNER DIA. - 1.0659 INCHES; TAP SEPARATION - 18.364 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	16.1	0.00	1.016	.0060	147.16	0.44	5.79	0.0209	54744
2	24.0	0.01	2.140	.0040	146.79	0.19	8.64	0.0198	80499
3	28.1	0.01	2.899	.0023	145.74	0.09	10.11	0.0196	94185
4	31.5	0.09	3.606	.0162	144.95	0.09	11.31	0.0195	105630
5	28.0	0.05	2.873	.0109	145.70	0.05	10.06	0.0196	93956
6	31.4	0.13	3.593	.0295	144.78	0.06	11.28	0.0195	105361
7	23.5	0.01	2.084	.0009	145.33	0.04	8.44	0.0202	78794
8	20.3	0.01	1.583	.0026	145.82	0.10	7.29	0.0206	67602
9	15.9	0.02	1.008	.0045	145.85	0.44	5.72	0.0213	52988
10	20.3	0.01	1.597	.0087	145.27	0.41	7.30	0.0207	67669

Table 2 (cont.)

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 1.25A

DATE 1/11/80 OBSERVERS - JM JH

AVE. INNER DIA. - 1.3813 INCHES; TAP SEPARATION - 17.833 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	27.5	0.14	0.699	.0056	153.03	0.13	5.89	0.0187	72089
2	35.0	0.11	1.102	.0008	152.22	0.46	7.49	0.0182	92005
3	42.3	0.02	1.573	.0013	151.84	0.14	9.06	0.0178	111216
4	47.7	0.01	1.959	.0033	151.86	0.15	10.20	0.0174	125264
5	55.1	0.02	2.599	.0035	150.83	0.10	11.81	0.0173	144937
6	55.5	0.06	2.641	.0025	150.36	0.19	11.87	0.0174	145769
7	47.8	0.03	1.983	.0029	151.29	0.18	10.23	0.0176	125934
8	41.8	0.01	1.558	.0017	150.60	0.12	8.94	0.0181	110338
9	34.1	0.03	1.070	.0017	150.76	0.14	7.30	0.0186	90140
10	27.2	0.01	0.705	.0017	150.54	0.17	5.82	0.0193	71870
11	54.8	0.07	2.596	.0121	150.03	0.55	11.74	0.0175	140805

AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1.25B

DATE 1/11/80 OBSERVERS - JM & JH

AVE. INNER DIA. - 1.3892 INCHES; TAP SEPARATION - 17.572 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	26.4	0.02	0.682	.0026	145.51	0.26	5.59	0.0206	67691
2	33.9	0.02	1.096	.0024	144.30	0.12	7.17	0.0202	86746
3	40.5	0.08	1.551	.0044	142.93	0.12	8.56	0.0200	103682
4	45.4	0.13	1.911	.0033	143.23	0.40	9.61	0.0196	116303
5	52.8	0.01	2.589	.0051	141.35	0.13	11.17	0.0196	135229
6	53.3	0.04	2.647	.0046	141.18	0.16	11.29	0.0196	139009
7	45.7	0.02	1.951	.0034	142.69	0.13	9.68	0.0197	119146
8	40.6	0.01	1.566	.0019	142.72	0.09	8.60	0.0201	105830
9	33.9	0.05	1.106	.0047	143.74	0.14	7.17	0.0203	88302
10	26.8	0.01	0.709	.0011	144.53	0.13	5.67	0.0209	69821

Table 2 (cont.)

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 1.5B  
 DATE JAN 4 80 OBSERVERS - JH & MH  
 AVE. INNER DIA. - 1.6238 INCHES; TAP SEPARATION - 17.177 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	59.1	0.07	1.268	.0021	152.51	0.06	9.15	0.0172	127414
2	68.7	0.16	1.684	.0085	151.97	0.13	10.64	0.0169	148472
3	75.8	0.29	2.036	.0144	151.48	0.15	11.75	0.0167	164334
4	76.1	0.13	2.050	.0086	151.43	0.09	11.79	0.0168	165193
5	68.1	0.21	1.665	.0105	151.66	0.06	10.55	0.0170	148326
6	61.3	0.47	1.373	.0215	151.55	0.83	9.50	0.0173	133924
7	75.6	0.08	2.076	.0023	149.39	0.21	11.71	0.0172	160966
8	104.2	1.54	3.892	.0395	146.62	2.35	16.14	0.0170	222594
9	99.6	0.31	3.540	.0164	147.60	0.16	15.44	0.0169	213368
10	76.6	0.14	2.151	.0084	148.66	0.13	11.88	0.0173	164574
11	46.6	0.42	0.857	.0145	148.68	0.32	7.22	0.0186	101049
12	36.4	0.04	0.535	.0025	149.89	0.23	5.65	0.0191	78997
13	36.7	0.01	0.545	.0016	149.63	0.23	5.69	0.0191	79661
14	47.0	0.01	0.869	.0007	148.85	0.08	7.29	0.0186	101979

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 2A  
 DATE 12/28-31/7 OBSERVERS - JH VB  
 AVE. INNER DIA. - 2.0665 INCHES; TAP SEPARATION - 16.385 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	61.9	0.05	0.414	.0018	151.23	0.28	5.92	0.0180	103874
2	75.7	0.33	0.616	.0073	149.11	0.31	7.24	0.0179	127502
3	89.1	0.21	0.854	.0018	147.13	0.33	8.52	0.0179	150607
4	105.2	0.14	1.189	.0064	145.28	0.28	10.07	0.0179	178424
5	119.4	0.13	1.537	.0060	143.47	0.32	11.42	0.0179	202978
6	134.9	0.70	1.997	.0059	140.75	0.82	12.91	0.0182	230155
7	133.0	0.27	1.986	.0087	139.10	0.47	12.72	0.0187	221604
8	116.2	0.39	1.542	.0077	139.40	0.51	11.11	0.0190	194350
9	101.0	0.83	1.197	.0206	139.00	0.69	9.66	0.0195	169480
10	85.7	0.55	0.895	.0083	138.75	0.72	8.19	0.0201	144137
11	70.9	0.18	0.628	.0048	138.14	0.61	6.78	0.0208	119505
12	54.5	0.18	0.387	.0030	138.14	0.37	5.22	0.0216	92076

Table 2 (cont.)

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 2B

DATE 1/2/80 OBSERVERS - JH VB MH

AVE. INNER DIA. - 2.0919 INCHES; TAP SEPARATION - 16.125 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	146.6	0.13	1.974	.0027	147.77	0.13	13.69	0.0165	240938
2	127.1	0.06	1.504	.0027	148.37	0.13	11.86	0.0167	209545
3	111.9	0.12	1.182	.0023	148.77	0.18	10.44	0.0170	184669
4	95.3	0.31	0.874	.0043	149.15	0.36	8.89	0.0173	157770
5	78.6	0.32	0.607	.0038	149.86	0.18	7.34	0.0177	130439
6	62.5	0.32	0.394	.0029	150.44	0.24	5.84	0.0181	103915
7	112.5	0.21	1.219	.0009	147.07	0.22	10.50	0.0173	185833
8	126.4	0.10	1.547	.0018	145.32	0.14	11.80	0.0174	209685
9	144.4	0.12	2.018	.0028	143.82	0.16	13.48	0.0174	240206
10	94.5	0.10	0.879	.0026	147.43	0.27	8.82	0.0177	157799
11	78.4	0.17	0.618	.0022	147.98	0.41	7.32	0.0181	131420
12	60.5	0.65	0.380	.0096	148.61	0.76	5.65	0.0186	101736

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 2.5A

DATE 12/19/79 OBSERVERS - JH VB

AVE. INNER DIA. - 2.474 INCHES; TAP SEPARATION - 15.552 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	84.5	1.60	0.288	.0096	152.11	0.32	5.64	0.0174	117890
2	109.3	2.08	0.482	.0150	148.78	0.50	7.29	0.0175	152946
3	131.0	0.57	0.685	.0064	147.50	0.30	8.74	0.0173	183774
4	152.9	1.72	0.927	.0236	146.15	0.62	10.20	0.0172	212909
5	200.1	0.72	1.581	.0086	143.41	0.14	13.36	0.0171	280002
6	175.7	0.22	1.245	.0015	143.21	0.13	11.72	0.0174	246643
7	208.6	0.55	1.587	.0105	149.13	0.16	13.92	0.0158	291264
8	184.4	0.38	1.259	.0086	149.45	0.27	12.31	0.0160	258119
9	152.9	0.17	0.899	.0023	148.62	0.22	10.21	0.0166	214902
10	132.3	0.07	0.689	.0027	148.54	0.27	8.83	0.0170	186511
11	111.0	0.02	0.498	.0017	148.44	0.28	7.41	0.0175	156964
12	83.1	0.41	0.290	.0029	148.86	0.35	5.55	0.0182	117875

Table 2 (cont.)

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 3A

DATE 12/21/79 OBSERVERS - VB &amp; JH

AVE. INNER DIA. - 3.0738 INCHES; TAP SEPARATION - 14.469 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	499.4	1.03	3.278	.0106	131.03	0.12	21.59	0.0182	545252
2	300.3	1.16	1.241	.0114	133.19	0.28	12.98	0.0190	331702
3	276.2	4.97	1.079	.0373	132.15	0.21	11.94	0.0195	301149
4	240.0	0.23	0.806	.0020	134.38	0.21	10.38	0.0194	262850
5	202.3	0.34	0.581	.0021	135.19	0.41	8.74	0.0196	223167
6	160.2	0.59	0.364	.0037	137.87	0.62	6.93	0.0196	177457
7	121.1	0.04	0.209	.0040	140.76	1.43	5.24	0.0197	134573
8	99.2	0.02	0.140	.0027	143.10	1.50	4.29	0.0197	110522
9	122.3	1.55	0.210	.0056	141.85	0.32	5.29	0.0194	138627
10	158.1	0.68	0.363	.0025	136.21	0.16	6.83	0.0201	179709
11	193.3	0.87	0.580	.0066	129.35	0.29	8.36	0.0215	219928
12	224.7	1.43	0.805	.0106	125.95	0.14	9.72	0.0220	256802
13	237.1	0.81	0.913	.0059	124.18	0.14	10.25	0.0224	271831
14	256.5	0.95	1.082	.0085	122.57	0.14	11.09	0.0227	294884

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 3B

DATE DEC 19 &amp; 2 OBSERVERS - JH VB MH

AVE. INNER DIA. - 3.0994 INCHES; TAP SEPARATION - 13.635 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	99.7	1.43	0.098	.0023	164.87	0.89	4.24	0.0151	109968
2	117.1	1.52	0.138	.0035	161.54	0.67	4.98	0.0153	129492
3	161.3	1.19	0.264	.0035	156.50	0.37	6.86	0.0155	179054
4	206.2	0.99	0.429	.0037	153.80	0.25	8.77	0.0154	229464
5	231.1	1.14	0.540	.0053	152.26	0.21	9.83	0.0155	255430
6	281.9	1.94	0.805	.0113	149.66	0.19	11.99	0.0155	312485
7	285.7	0.20	0.794	.0007	152.89	0.10	12.15	0.0149	314463
8	233.9	0.11	0.540	.0011	154.09	0.16	9.95	0.0151	258407
9	208.6	0.61	0.434	.0027	154.68	0.13	8.87	0.0153	231100
10	161.4	1.03	0.263	.0035	156.81	0.21	6.86	0.0155	179282
11	113.7	0.67	0.133	.0018	159.68	0.30	4.84	0.0158	126983
12	95.0	1.01	0.092	.0021	162.59	0.65	4.04	0.0157	106285

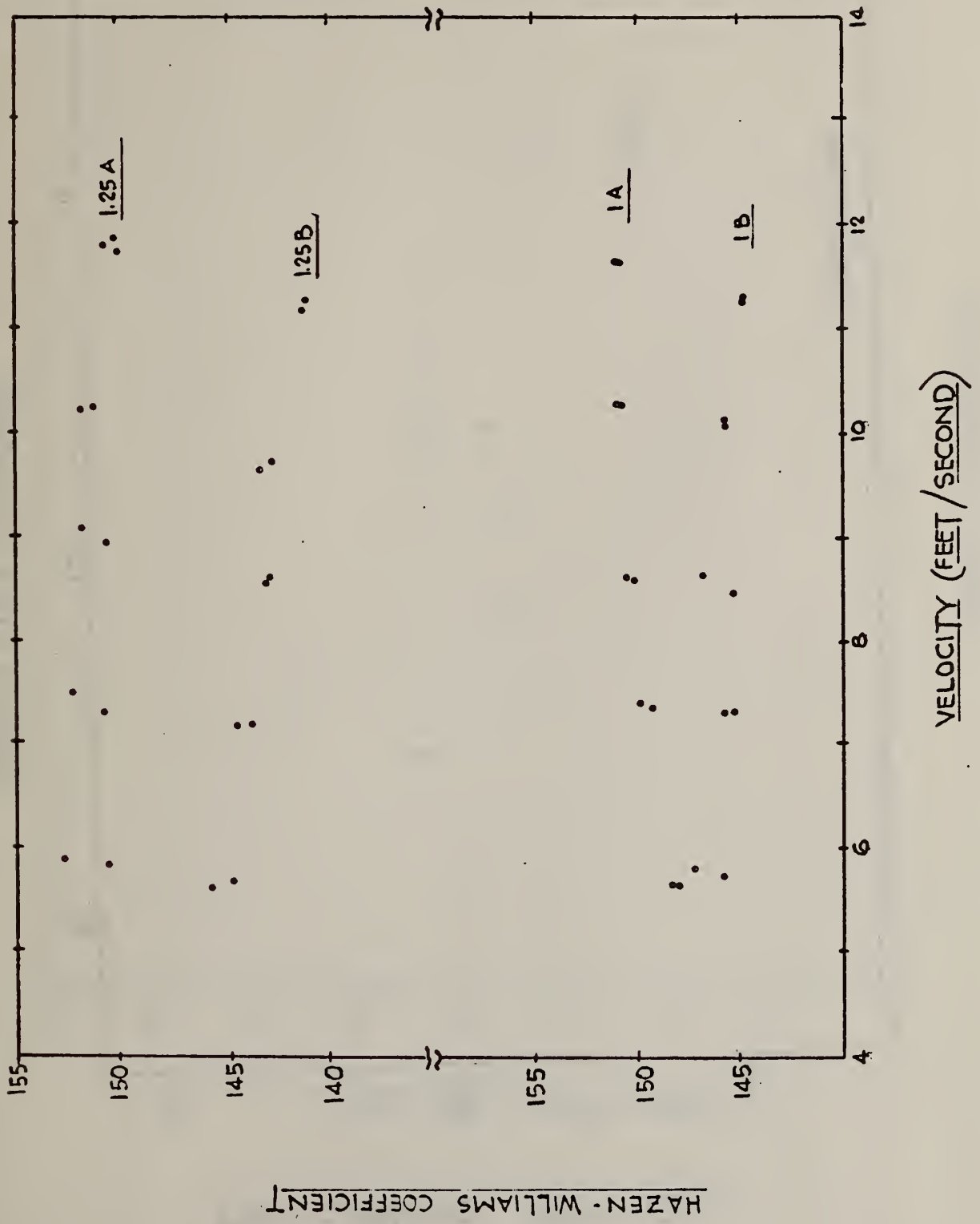


Figure 1

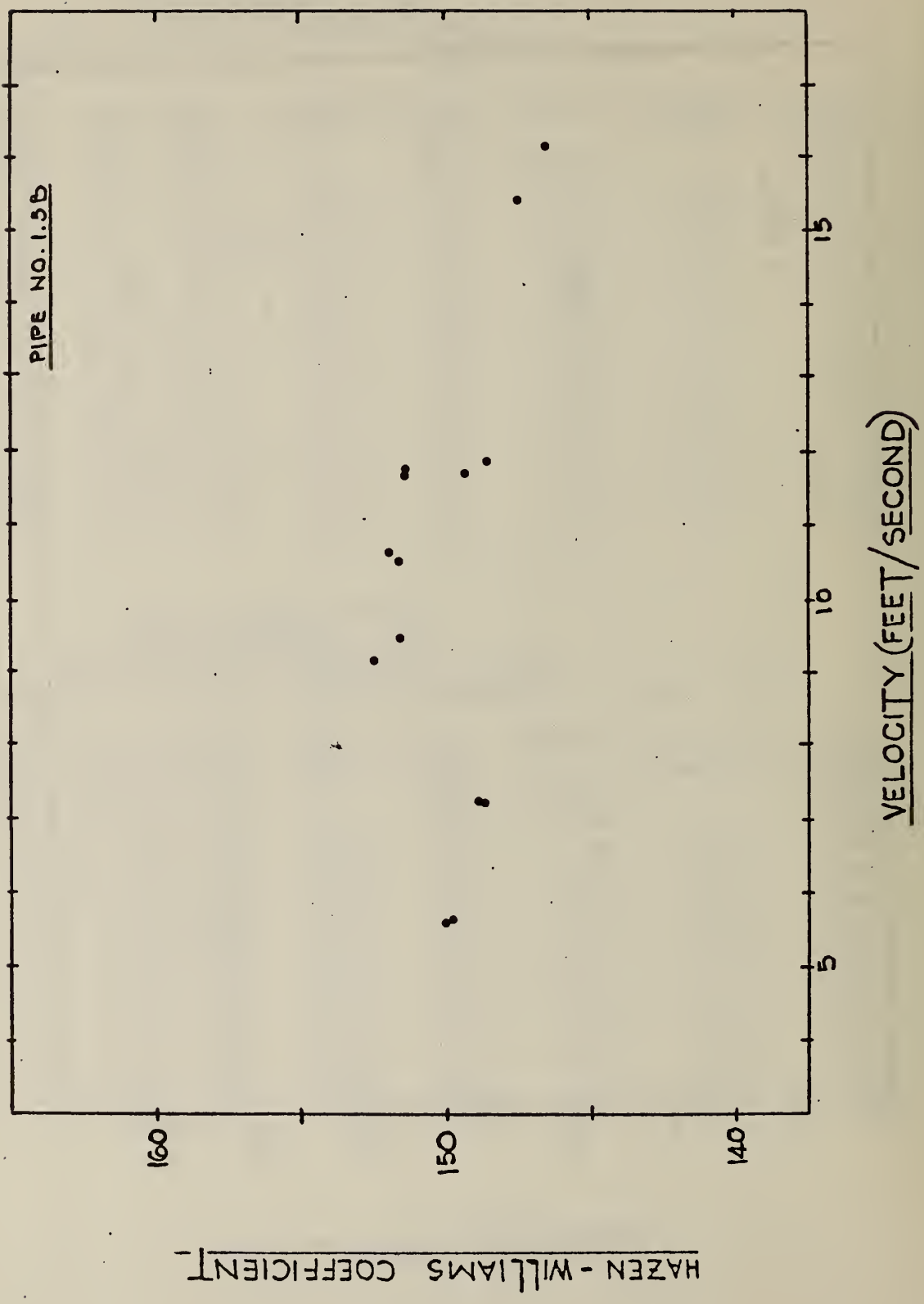


Figure 2



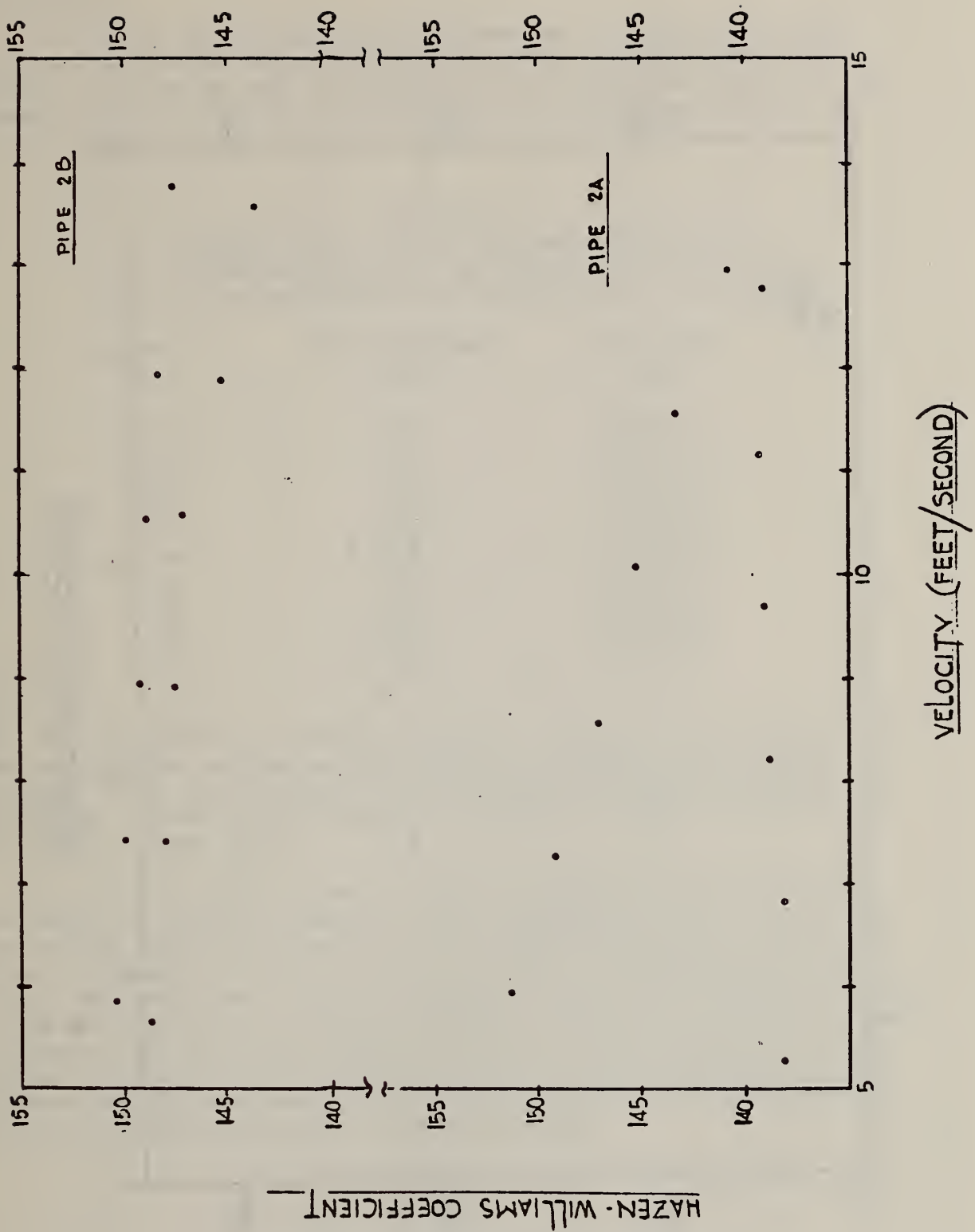


Figure 3

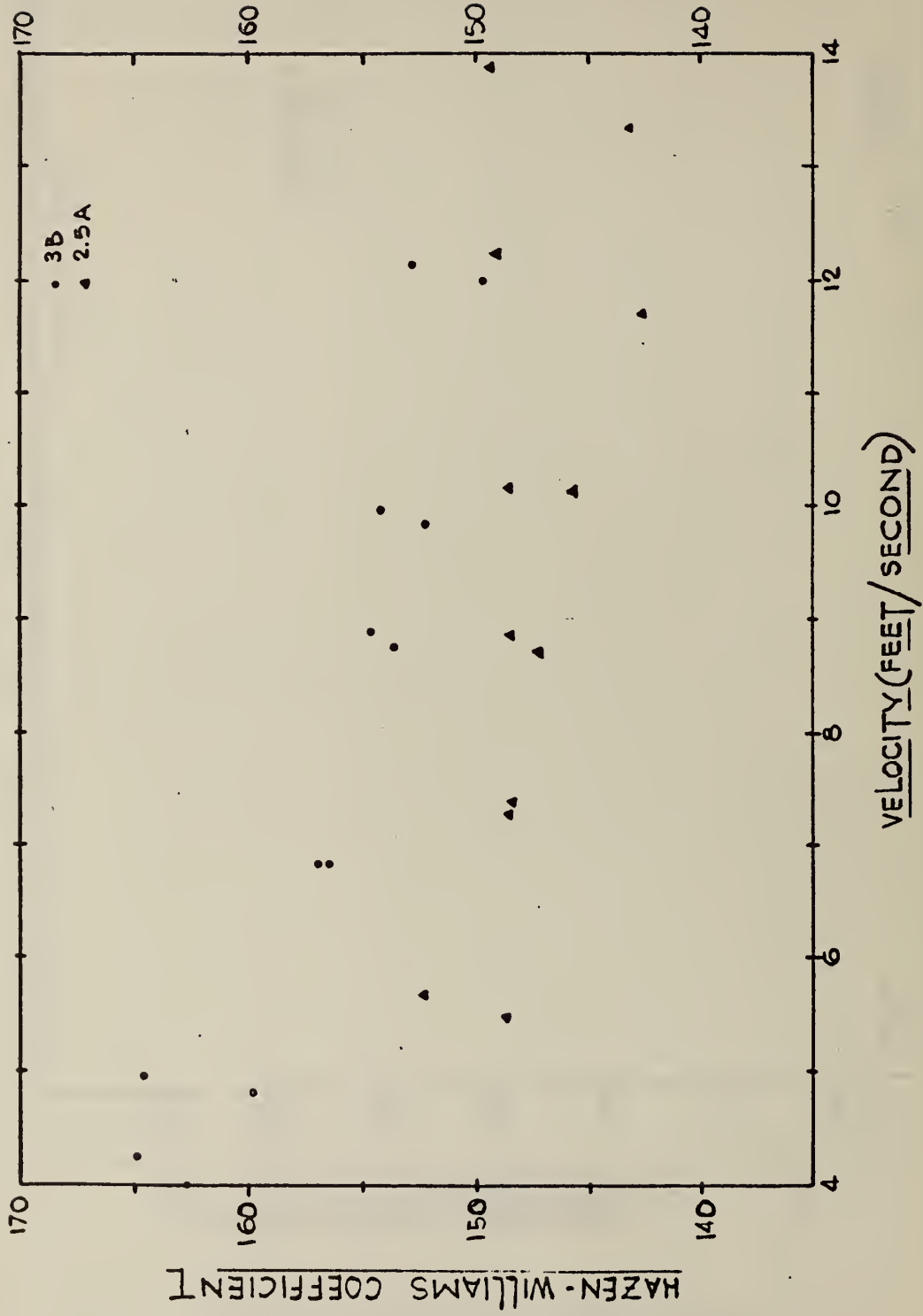


Figure 4

## Conclusions

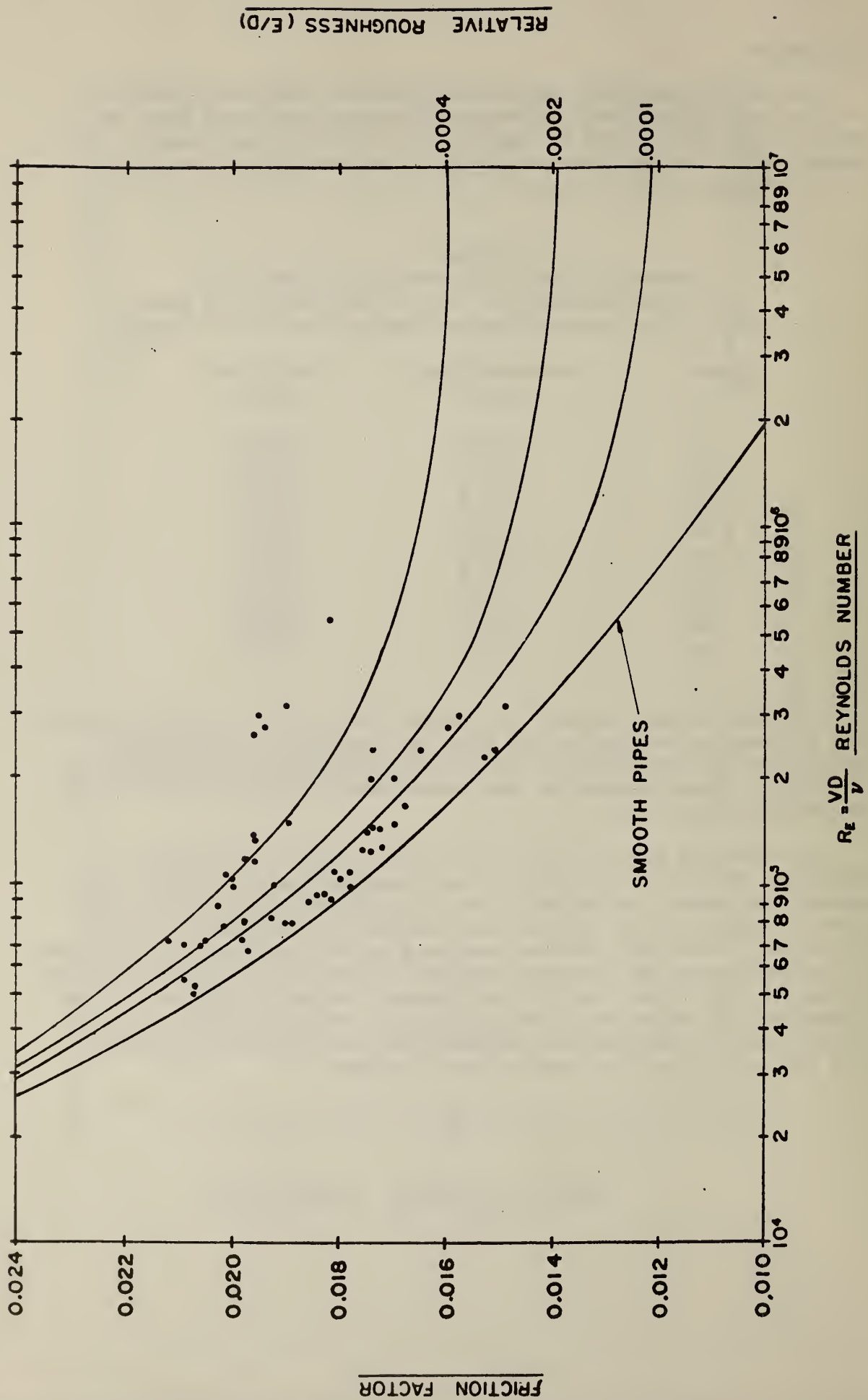
Due to the relatively small dependence on flowrate of the Hazen-Williams coefficient over the range of flowrate considered here, an average value may be used to characterize the frictional losses in the pipes. Table 3 gives these averages for the coefficients for the various pipes.

Table 3  
Average Values of Hazen-Williams Coefficient  
For a Flowrate Range of 4 to 16 Feet/Second for Black  
Steel Pipes Having Diameters Ranging From 1 to 3 Inches

Ident. No.	Hazen-Williams Mean	Coefficient Range
1A	150.0	148-151
1B	145.7	144-147
1.25A	151.2	150-153
1.25B	143.2	141-145
1.5B	150.0	148-153
2A	142.5	138-151
2B	147.9	143-151
2.5A	147.8	143-152
3A	133.4	122-143
3B	156.6	149-165

The relationship between the friction factor and the relative roughness of the pipe, defined as the ratio of the height of the surface features to the pipe diameter was developed by Colebrook and Moody. A portion of a Moody diagram has been reproduced in figure 5 which covers the range of these tests.

The friction factors for all pipe sizes below three inches are indicative of relative roughness values ranging from .0004 down to the smooth pipe curve. The points which lie significantly above the .0004 curve are those for the 3A pipe which exhibit the increased friction factor and, therefore, relative roughness caused by the prolonged exposure of the specimen to the corrosive effects of the fully aerated water used throughout this test. The friction factors for the 3B specimen are not plotted but lie below the smooth pipe curve. With the exception of the 3B pipe the friction factors inferred from this test are in agreement with the values expected from the Moody diagram.



$$R_E = \frac{VD}{\nu} \text{ REYNOLDS NUMBER}$$

Figure 5

## References

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2. Nikuradse, J., "Stromungsgesetze in rauhen Rohren," VDI-Forschungsheft, 361, 1933. Translation available in NACA, Tech. Mem. 1292.
3. Colebrook, C. F., "Turbulent Flow in Pipes, with Particular Reference to the Transition Region between the Smooth and Rough Pipe Laws," Jour. Inst. Civil Engrs., London, p. 133, Feb. 1939.
4. Moody, L. F., "Friction Factors for Pipe Flow," Trans. ASME, Vol. 66, p. 671.
5. Williams, G. S. and Hazen, A., Hydraulic Tables, Third Ed., John Wiley and Sons, 1933.
6. Wagenbreth, H. and Blanche, W., PTB-Mitt. S8425F.



Appendix

Tables of Data and Results





## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1A

DATE JAN 9 80

OBSERVERS - JM PB

AVE. INNER DIA. - 1.0557 INCHES; TAP SEPARATION - 18.859 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	--- MANOMETER ---		WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER
				HEIGHT (INCH)	STD. DEV. (INCH)						
HAND. FLUID -- WATER			BAROMETER -- 75.81		CM OF MERCURY	AIR TEMPERATURE -- 20.95	DEGREES CELCIUS				
1	0.0	200.0	93.448	27.770	0.127	21.80	24.86	110.30	15.4	0.9966	148.26 51043.5
2	0.0	200.0	93.633	27.635	0.089	22.10	24.86	110.20	15.4	0.9917	148.36 50942.6
3	0.0	200.0	93.890	27.495	0.091	22.20	24.86	110.30	15.4	0.9867	148.37 50803.2
4	0.0	200.0	93.925	27.513	0.120	22.30	24.86	110.30	15.4	0.9873	148.26 50784.2
5	0.0	200.0	93.976	27.460	0.193	22.40	24.86	110.20	15.4	0.9854	148.34 50756.7
HAND. FLUID -- WATER			BAROMETER -- 75.81		CM OF MERCURY	AIR TEMPERATURE -- 21.27	DEGREES CELCIUS				
6	0.0	200.0	72.389	44.000	0.079	22.40	24.86	109.50	19.9	1.5789	149.25 65892.7
7	0.0	200.0	71.804	44.566	0.130	22.50	24.86	109.40	20.1	1.5992	149.43 66429.5
8	0.0	200.0	71.813	44.564	0.111	22.50	25.27	109.40	20.1	1.5991	149.43 66984.4
9	0.0	200.0	71.823	44.703	0.146	22.60	25.27	109.50	20.1	1.6041	149.16 66975.1
10	0.0	200.0	71.846	44.635	0.086	22.55	25.27	109.40	20.1	1.6017	149.23 66953.7
HAND. FLUID -- HG			BAROMETER -- 75.83		CM OF MERCURY	AIR TEMPERATURE -- 21.47	DEGREES CELCIUS				
11	0.0	200.0	61.440	4.598	0.009	21.40	25.27	110.00	23.5	2.0933	151.00 78293.4
12	0.0	200.0	61.415	4.611	0.005	21.30	25.27	110.00	23.5	2.0996	150.82 78325.3
13	0.0	200.0	61.430	4.622	0.008	21.35	25.27	110.00	23.5	2.1046	150.59 78306.0
14	0.0	200.0	61.406	4.646	0.008	21.40	25.27	110.00	23.5	2.1154	150.23 78336.8
15	0.0	200.0	61.407	4.661	0.007	21.40	25.27	110.00	23.5	2.1222	149.96 78335.5
HAND. FLUID -- HG			BAROMETER -- 75.82		CM OF MERCURY	AIR TEMPERATURE -- 21.48	DEGREES CELCIUS				
16	0.0	200.0	51.519	6.365	0.014	21.40	25.27	110.00	28.0	2.8981	151.04 93370.4
17	0.0	200.0	51.508	6.369	0.015	21.50	25.27	110.00	28.0	2.8999	151.02 93390.3
18	0.0	200.0	51.528	6.368	0.016	21.50	25.27	110.00	28.0	2.8995	150.97 93354.1
19	0.0	200.0	51.533	6.363	0.016	21.55	25.27	110.00	28.0	2.8973	151.02 93345.0
20	0.0	200.0	51.504	6.380	0.011	21.60	25.27	110.00	28.0	2.9048	150.89 93397.6
HAND. FLUID -- HG			BAROMETER -- 75.81		CM OF MERCURY	AIR TEMPERATURE -- 21.59	DEGREES CELCIUS				
21	0.0	200.0	45.450	8.053	0.028	21.60	25.27	110.00	31.7	3.6666	150.77 105838.0
22	0.0	200.0	45.456	8.051	0.025	21.60	25.27	110.00	31.7	3.6658	150.76 105824.0
23	0.0	200.0	45.424	8.038	0.032	21.70	25.27	110.00	31.8	3.6596	151.01 105899.0
24	0.0	200.0	45.508	8.007	0.010	21.70	25.27	110.00	31.7	3.6454	151.05 105703.0
25	0.0	200.0	45.543	8.004	0.019	21.65	25.27	110.00	31.7	3.6442	150.96 105622.0
HAND. FLUID -- HG			BAROMETER -- 75.81		CM OF MERCURY	AIR TEMPERATURE -- 20.7	DEGREES CELCIUS				
26	0.0	200.0	45.463	8.046	0.023	21.70	25.75	110.00	31.7	3.6635	150.81 106855.0
27	0.0	200.0	45.481	8.030	0.019	21.75	25.75	110.00	31.7	3.6560	150.92 106812.0
28	0.0	200.0	45.545	8.028	0.016	21.80	25.75	110.00	31.7	3.6552	150.73 106662.0
29	0.0	200.0	45.521	8.024	0.016	21.80	25.75	110.00	31.7	3.6532	150.85 106718.0
30	0.0	200.0	45.545	8.007	0.006	21.80	25.42	110.00	31.7	3.6457	150.92 105944.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1A

DATE JAN 9 80

OBSERVERS - JH PB

AVE. INNER DIA. - 1.0557 INCHES; TAP SEPARATION - 18.359 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	---- MANOMETER HEIGHT (INCH)	---- STD. DEV. (DEG C)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPH)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
HAND. FLUID -- HG			BAROMETER -- 75.81		CM OF MERCURY		AIR TEMPERATURE -- 21.75		DEGREES CELCIUS			
31	0.0	200.0	51.553	6.375	0.010	21.80	25.75	110.00	28.0	2.9027	150.83	94231.3
32	0.0	200.0	51.604	6.374	0.009	21.90	25.41	110.00	28.0	2.9019	150.89	93484.9
33	0.0	200.0	51.602	6.360	0.018	21.90	25.75	110.00	28.0	2.8955	150.89	94141.8
34	0.0	200.0	51.551	6.365	0.012	21.90	25.75	110.00	28.0	2.8981	150.96	94235.0
35	0.0	200.0	51.586	6.375	0.012	21.90	25.75	110.00	28.0	2.9023	150.74	94171.0
HAND. FLUID -- HG			BAROMETER -- 75.81		CM OF MERCURY		AIR TEMPERATURE -- 21.8		DEGREES CELCIUS			
36	0.0	200.0	61.657	4.619	0.017	21.90	25.75	110.00	23.4	2.1031	150.11	78787.2
37	0.0	200.0	61.709	4.610	0.007	21.90	25.42	110.00	23.4	2.0989	150.13	78193.8
38	0.0	200.0	61.715	4.607	0.008	21.95	25.75	110.00	23.4	2.0975	150.12	78715.1
39	0.0	200.0	61.786	4.603	0.005	22.00	25.42	110.00	23.4	2.0957	150.06	78095.1
40	0.0	200.0	61.769	4.604	0.005	22.00	25.75	110.00	23.4	2.0961	150.11	78645.3
HAND. FLUID -- WATER			BAROMETER -- 75.8		CM OF MERCURY		AIR TEMPERATURE -- 21.89		DEGREES CELCIUS			
41	0.0	200.0	71.738	44.497	0.170	22.95	25.41	108.90	20.1	1.5966	149.72	67247.3
42	0.0	200.0	71.758	44.632	0.085	22.90	25.41	108.80	20.1	1.6015	149.43	67228.6
43	0.0	200.0	71.000	44.617	0.053	23.00	25.41	108.90	20.3	1.6009	151.06	67945.3
44	0.0	200.0	71.776	44.652	0.100	23.05	25.41	108.90	20.1	1.6025	149.34	67211.7
45	0.0	200.0	71.790	44.617	0.103	23.05	25.56	109.00	20.1	1.6008	149.40	67495.6
HAND. FLUID -- WATER			BAROMETER -- 75.79		CM OF MERCURY		AIR TEMPERATURE -- 21.98		DEGREES CELCIUS			
46	0.0	200.0	92.171	28.532	0.102	23.25	25.56	109.70	15.7	1.0237	148.18	52500.7
47	0.0	200.0	92.219	28.443	0.075	23.25	25.56	109.80	15.6	1.0205	148.35	52473.4
48	0.0	200.0	92.238	28.381	0.128	23.40	25.56	109.90	15.6	1.0182	148.50	52462.6
49	0.0	200.0	92.221	28.409	0.153	23.40	25.56	109.90	15.6	1.0192	148.45	52472.3
50	0.0	200.0	92.259	28.420	0.192	23.50	25.56	109.80	15.6	1.0196	148.36	52450.7

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1A

DATE JAN 9 80 OBSERVERS - JM PB

AVE. INNER DIA. - 1.0557 INCHES; TAP SEPARATION - 18.859 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	15.4	0.04	0.990	.0046	148.32	0.05	5.64	0.0207	50866
2	20.1	0.07	1.597	.0101	149.30	0.12	7.35	0.0197	66647
3	23.5	0.01	2.107	.0117	150.52	0.42	8.61	0.0189	78319
4	28.0	0.01	2.900	.0030	150.99	0.06	10.27	0.0183	93371
5	31.7	0.03	3.656	.0109	150.91	0.13	11.63	0.0180	105777
6	31.7	0.03	3.655	.0064	150.85	0.08	11.62	0.0180	106598
7	28.0	0.01	2.900	.0031	150.82	0.11	10.25	0.0184	94053
8	23.4	0.02	2.098	.0030	150.12	0.04	8.57	0.0190	78488
9	20.1	0.10	1.600	.0023	149.79	0.72	7.39	0.0196	67408
10	15.6	0.01	1.020	.0021	148.37	0.12	5.73	0.0207	52472

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1B

DATE JAN 9 80

OBSERVERS - MH &amp; JK

AVE. INNER DIA. - 1.0359 INCHES; TAP SEPARATION - 18.354 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	TIERT TIME (SEC)	---- MANOMETER HEIGHT (INCH)	---- STD. DEV. (DEG C)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
HAND. FLUID -- WATER			BAROMETER -- 75.77			CM OF MERCURY	AIR TEMPERATURE -- 22.42		DEGREES CELCIUS			
1	0.0	200.0	89.557	28.570	0.173	23.90	26.69	116.40	16.1	1.0245	146.55	54762.2
2	0.0	200.0	89.582	28.454	0.028	24.00	26.69	116.40	16.1	1.0204	146.83	54746.9
3	0.0	200.0	89.611	28.222	0.422	24.10	26.69	116.50	16.1	1.0120	147.44	54729.2
4	0.0	200.0	89.577	28.215	0.255	24.10	26.69	116.50	16.1	1.0118	147.51	54750.0
5	0.0	200.0	89.608	28.212	0.213	24.20	26.69	116.50	16.1	1.0116	147.47	54731.0
HAND. FLUID -- HG			BAROMETER -- 75.79			CM OF MERCURY	AIR TEMPERATURE -- 22.77		DEGREES CELCIUS			
26	0.0	200.0	60.025	4.691	0.016	22.80	25.97	0.00	24.0	2.1354	146.98	89517.6
27	0.0	200.0	60.003	4.696	0.016	22.80	25.97	0.00	24.1	2.1390	146.94	89547.1
28	0.0	200.0	60.056	4.699	0.024	22.85	25.97	0.00	24.0	2.1394	146.76	89476.0
29	0.0	200.0	60.050	4.700	0.013	22.90	25.97	0.00	24.0	2.1397	146.76	89494.0
30	0.0	200.0	60.060	4.714	0.026	22.90	25.97	0.00	24.0	2.1462	146.49	89470.6
HAND. FLUID -- HG			BAROMETER -- 75.78			CM OF MERCURY	AIR TEMPERATURE -- 22.81		DEGREES CELCIUS			
31	0.0	200.0	51.303	6.362	0.029	22.90	25.97	0.00	28.1	2.8963	145.85	94206.3
32	0.0	200.0	51.307	6.365	0.026	22.90	25.97	0.00	28.1	2.8977	145.80	94193.9
33	0.0	200.0	51.292	6.371	0.029	22.90	25.97	0.00	28.1	2.9004	145.77	94226.5
34	0.0	200.0	51.322	6.375	0.023	22.90	25.97	0.00	28.1	2.9022	145.63	94171.4
35	0.0	200.0	51.348	6.367	0.021	23.00	25.97	0.00	28.1	2.8986	145.66	94123.7
HAND. FLUID -- HG			BAROMETER -- 75.79			CM OF MERCURY	AIR TEMPERATURE -- 22.82		DEGREES CELCIUS			
36	0.0	200.0	45.716	7.969	0.040	23.00	26.11	0.00	31.6	3.6279	144.92	106021.0
37	0.0	200.0	45.804	7.936	0.054	23.00	26.11	0.00	31.5	3.6128	144.96	105818.0
38	0.0	200.0	45.890	7.929	0.025	23.00	26.11	0.00	31.5	3.6095	144.80	105643.0
39	0.0	200.0	45.996	7.893	0.043	23.00	26.11	0.00	31.4	3.5910	144.83	105376.0
40	0.0	200.0	46.033	7.894	0.023	23.00	26.11	0.00	31.4	3.5892	144.76	105291.0
HAND. FLUID -- HG			BAROMETER -- 75.76			CM OF MERCURY	AIR TEMPERATURE -- 22.83		DEGREES CELCIUS			
41	0.0	200.0	51.423	6.348	0.039	23.00	26.11	0.00	28.1	2.8397	145.69	94255.0
42	0.0	200.0	51.561	6.320	0.027	23.10	26.11	0.00	28.0	2.8771	145.64	94032.7
43	0.0	200.0	51.662	6.294	0.016	23.05	26.11	0.00	27.9	2.8654	145.69	93819.0
44	0.0	200.0	51.633	6.293	0.023	23.05	26.11	0.00	28.0	2.8648	145.78	93971.7
45	0.0	200.0	51.654	6.295	0.020	23.10	26.11	0.00	27.9	2.8657	145.69	93833.5
HAND. FLUID -- HG			BAROMETER -- 75.76			CM OF MERCURY	AIR TEMPERATURE -- 22.88		DEGREES CELCIUS			
46	0.0	200.0	45.721	7.983	0.030	23.15	26.11	0.00	31.6	3.6365	144.72	106010.0
47	0.0	200.0	45.943	7.913	0.027	23.20	26.11	0.00	31.4	3.6023	144.75	105498.0
48	0.0	200.0	46.113	7.859	0.032	23.20	26.11	0.00	31.3	3.5773	144.76	105109.0
49	0.0	200.0	46.250	7.815	0.016	23.10	26.11	0.00	31.2	3.5577	144.76	104797.0
50	0.0	200.0	45.989	7.895	0.030	23.15	26.11	0.00	31.4	3.5996	144.89	105392.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1B

DATE JAN 9 89

OBSERVERS - MH &amp; JH

AVE. INNER DIA. - 1.0659 INCHES; TAP SEPARATION - 18.364 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	---- MANDMETER ---- HEIGHT (INCH)	STD. DEV. (INCH)	WATER TEMP. (DEG C)	TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER
MAND. FLUID -- HG				BAROMETER -- 75.76 CM OF MERCURY				AIR TEMPERATURE -- 22.88 DEGREES CELCIUS				
51	0.0	200.0	61.484	4.578	0.041	23.20	26.11	0.00	23.5	2.0841	145.37	78931.5
52	0.0	200.0	61.494	4.581	0.022	23.20	26.11	0.00	23.5	2.0853	145.33	78918.7
53	0.0	200.0	61.521	4.578	0.027	23.20	26.11	0.00	23.5	2.0842	145.30	78794.1
54	0.0	200.0	61.521	4.577	0.029	23.20	26.11	0.00	23.5	2.0838	145.32	78794.1
55	0.0	200.0	61.547	4.575	0.027	23.20	26.11	0.00	23.4	2.0827	145.30	78750.8
MAND. FLUID -- WATER				BAROMETER -- 75.77 CM OF MERCURY				AIR TEMPERATURE -- 23.18 DEGREES CELCIUS				
56	0.0	200.0	71.101	44.225	0.078	24.40	25.72	115.50	20.3	1.5858	145.72	67628.2
57	0.0	200.0	71.089	44.175	0.060	24.40	25.72	115.70	20.3	1.5840	145.84	67639.7
58	0.0	200.0	71.142	44.135	0.162	24.40	25.72	115.70	20.3	1.5826	145.80	67589.3
59	0.0	200.0	71.144	44.027	0.115	24.40	25.72	115.60	20.3	1.5787	145.99	67587.4
60	0.0	200.0	71.168	44.127	0.261	24.40	25.72	116.10	20.3	1.5823	145.76	67564.6
MAND. FLUID -- WATER				BAROMETER -- 75.79 CM OF MERCURY				AIR TEMPERATURE -- 23.26 DEGREES CELCIUS				
61	0.0	200.0	90.974	28.220	0.140	24.40	25.72	116.50	15.9	1.0119	145.20	52855.1
62	0.0	200.0	90.615	28.211	0.168	24.40	25.72	116.60	15.9	1.0116	145.80	53064.5
63	0.0	200.0	90.672	28.196	0.162	24.40	25.72	116.60	15.9	1.0110	145.75	53031.1
64	0.0	200.0	90.732	27.991	0.215	24.40	25.72	116.40	15.9	1.0037	145.23	52996.0
65	0.0	200.0	90.736	27.973	0.164	24.50	25.72	116.50	15.9	1.0030	145.28	52993.7
MAND. FLUID -- WATER				BAROMETER -- 75.79 CM OF MERCURY				AIR TEMPERATURE -- 23.29 DEGREES CELCIUS				
66	0.0	200.0	71.026	44.662	0.202	24.40	25.72	115.70	20.3	1.6015	145.11	67699.6
67	0.0	200.0	71.046	44.562	0.275	24.40	25.72	115.70	20.3	1.5979	145.24	67690.6
68	0.0	200.0	71.059	44.568	0.147	24.40	25.72	115.50	20.3	1.5981	145.20	67668.2
69	0.0	200.0	71.090	44.122	0.264	24.40	25.72	115.50	20.3	1.5822	145.95	67649.2
70	0.0	200.0	71.078	44.745	0.297	24.40	25.72	115.00	20.3	1.6045	144.85	67650.1

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 1B  
 DATE JAN 9 80      OBSERVERS - KH & JH  
 AVE. INNER DIA. - 1.0659 INCHES; TAP SEPARATION - 19.364 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	16.1	0.00	1.016	.0060	147.16	0.44	5.79	0.0209	54744
2	24.0	0.01	2.140	.0040	146.79	0.19	8.64	0.0198	80499
3	28.1	0.01	2.899	.0023	145.74	0.09	10.11	0.0196	94185
4	31.5	0.09	3.606	.0162	144.85	0.09	11.31	0.0195	105630
5	28.0	0.05	2.873	.0109	145.70	0.05	10.06	0.0196	93956
6	31.4	0.13	3.593	.0295	144.78	0.06	11.28	0.0195	105361
7	23.5	0.01	2.084	.0009	145.33	0.04	8.44	0.0202	78794
8	20.3	0.01	1.583	.0026	145.82	0.10	7.29	0.0206	67602
9	15.9	0.02	1.008	.0045	145.85	0.44	5.72	0.0213	52988
10	20.3	0.01	1.597	.0087	145.27	0.41	7.30	0.0207	67669

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1.25A

DATE 1/11/80

OBSERVERS - JM JH

AVE. INNER DIA. - 1.3813 INCHES; TAP SEPARATION - 17.833 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	---- MANOMETER HEIGHT (INCH)	---- STD. DEV. (DEG C)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPH)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER
MANO. FLUID -- WATER      BAROMETER -- 75.51 CM OF MERCURY      AIR TEMPERATURE -- 21.92 DEGREES CELCIUS											
1	0.0	200.0	52.085	19.715	0.060	24.00	26.67	123.30	27.7	0.7068	153.21 72630.6
2	0.0	200.0	52.367	19.567	0.053	24.00	26.67	123.30	27.6	0.7015	153.01 72239.4
3	0.0	200.0	52.635	19.408	0.054	23.90	26.67	123.30	27.4	0.6958	152.90 71871.6
4	0.0	200.0	52.527	19.435	0.051	23.90	26.67	123.30	27.5	0.6968	153.10 72019.4
5	0.0	200.0	52.772	19.308	0.071	23.90	26.67	123.30	27.4	0.6922	152.93 71685.0
MANO. FLUID -- WATER      BAROMETER -- 75.5 CM OF MERCURY      AIR TEMPERATURE -- 22.04 DEGREES CELCIUS											
6	0.0	200.0	41.141	30.765	0.037	23.70	26.81	122.50	35.1	1.1030	152.50 92212.1
7	0.0	200.0	41.471	30.720	0.049	23.70	26.81	122.50	34.8	1.1014	151.40 91478.4
8	0.0	200.0	41.168	30.758	0.122	23.70	26.81	122.50	35.1	1.1028	152.42 92151.7
9	0.0	200.0	41.191	30.745	0.040	23.65	26.81	122.50	35.0	1.1023	152.36 92100.2
10	0.0	200.0	41.198	30.715	0.056	23.70	26.81	122.50	35.0	1.1013	152.42 92034.5
MANO. FLUID -- WATER      BAROMETER -- 75.46 CM OF MERCURY      AIR TEMPERATURE -- 22.1 DEGREES CELCIUS											
11	0.0	200.0	34.078	43.810	0.051	23.50	26.81	121.60	42.4	1.5709	152.08 111324.0
12	0.0	200.0	34.114	43.880	0.052	23.50	26.81	121.60	42.3	1.5734	151.78 111206.0
13	0.0	200.0	34.109	43.848	0.028	23.50	26.81	121.60	42.3	1.5722	151.87 111223.0
14	0.0	200.0	34.129	43.838	0.065	23.50	26.81	121.60	42.3	1.5719	151.80 111158.0
15	0.0	200.0	34.125	43.903	0.033	23.50	26.81	121.60	42.3	1.5742	151.69 111171.0
MANO. FLUID -- HG      BAROMETER -- 75.42 CM OF MERCURY      AIR TEMPERATURE -- 22.13 DEGREES CELCIUS											
16	0.0	200.0	30.278	4.292	0.024	21.75	26.81	121.50	47.7	1.9540	152.12 125295.0
17	0.0	200.0	30.281	4.309	0.012	21.80	26.81	121.50	47.7	1.9619	151.77 125283.0
18	0.0	200.0	30.289	4.308	0.019	21.80	26.81	121.50	47.7	1.9616	151.74 125250.0
19	0.0	200.0	30.297	4.301	0.023	21.80	26.81	121.50	47.6	1.9581	151.85 125217.0
20	0.0	200.0	30.283	4.306	0.018	21.80	26.81	121.50	47.7	1.9607	151.81 125275.0
MANO. FLUID -- HG      BAROMETER -- 75.4 CM OF MERCURY      AIR TEMPERATURE -- 22.2 DEGREES CELCIUS											
21	0.0	200.0	26.176	5.719	0.039	21.90	26.81	121.50	55.1	2.6038	150.66 144930.0
22	0.0	200.0	26.183	5.701	0.041	21.90	26.81	121.50	55.1	2.5956	150.88 144891.0
23	0.0	200.0	26.185	5.701	0.049	21.90	26.81	121.50	55.1	2.5956	150.87 144890.0
24	0.0	200.0	26.162	5.706	0.059	21.95	26.81	121.50	55.2	2.5979	150.93 145098.0
25	0.0	200.0	26.168	5.712	0.022	22.00	26.81	121.50	55.2	2.6006	150.81 144974.0
MANO. FLUID -- HG      BAROMETER -- 75.37 CM OF MERCURY      AIR TEMPERATURE -- 22.27 DEGREES CELCIUS											
26	0.0	200.0	25.995	5.799	0.018	22.00	26.81	121.50	55.5	2.6402	150.58 145939.0
27	0.0	200.0	26.071	5.797	0.020	22.00	26.81	121.50	55.4	2.6393	150.17 145514.0
28	0.0	200.0	26.005	5.797	0.016	22.05	26.81	121.50	55.5	2.6393	150.55 145833.0
29	0.0	200.0	26.029	5.809	0.020	22.05	26.81	121.50	55.5	2.6447	150.24 145748.0
30	0.0	200.0	26.027	5.806	0.016	22.05	26.81	121.50	55.5	2.6434	150.29 145760.0

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 1.25A  
 DATE 1/11/80 OBSERVERS - JM JH  
 AVE. INNER DIA. - 1.3813 INCHES; TAP SEPARATION - 17.833 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	MANOMETER HEIGHT (INCH)	MANOMETER STD. DEV. (INCH)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
HAND. FLUID -- HG				BAROMETER -- 75.35 CM OF MERCURY				AIR TEMPERATURE -- 22.33 DEGREES CELCIUS				
31	0.0	200.0	30.210	4.351	0.024	22.10	26.94	121.50	47.8	1.9810	151.34	125903.0
32	0.0	200.0	30.187	4.352	0.014	22.10	26.94	121.50	47.8	1.9859	151.25	126034.0
33	0.0	200.0	30.182	4.349	0.021	22.20	26.94	121.50	47.8	1.9800	151.52	126025.0
34	0.0	200.0	30.230	4.352	0.015	22.20	26.94	121.50	47.7	1.9860	151.03	125824.0
35	0.0	200.0	30.209	4.352	0.016	22.20	26.94	121.50	47.8	1.9814	151.33	125912.0
HAND. FLUID -- WATER				BAROMETER -- 75.29 CM OF MERCURY				AIR TEMPERATURE -- 22.46 DEGREES CELCIUS				
36	0.0	200.0	34.563	43.368	0.080	24.25	27.08	121.50	41.8	1.5548	150.79	110362.0
37	0.0	200.0	34.559	43.460	0.033	24.25	27.08	121.50	41.8	1.5581	150.64	110375.0
38	0.0	200.0	34.570	43.475	0.067	24.20	27.08	121.50	41.8	1.5586	150.56	110340.0
39	0.0	200.0	34.573	43.465	0.044	24.20	27.08	121.50	41.8	1.5583	150.56	110330.0
40	0.0	200.0	34.588	43.478	0.028	24.20	27.08	121.50	41.7	1.5587	150.48	110282.0
HAND. FLUID -- WATER				BAROMETER -- 75.26 CM OF MERCURY				AIR TEMPERATURE -- 22.5 DEGREES CELCIUS				
41	0.0	200.0	42.250	29.898	0.066	24.20	27.08	122.50	34.2	1.0718	150.83	90282.5
42	0.0	200.0	42.307	29.770	0.073	24.05	27.08	122.50	34.1	1.0673	150.97	90160.9
43	0.0	200.0	42.338	29.818	0.043	24.10	27.08	122.50	34.1	1.0690	150.73	90094.9
44	0.0	200.0	42.347	29.833	0.053	24.10	27.08	122.50	34.1	1.0695	150.66	90075.7
45	0.0	200.0	42.342	29.850	0.095	24.10	27.08	122.60	34.1	1.0701	150.63	90086.3
HAND. FLUID -- WATER				BAROMETER -- 75.22 CM OF MERCURY				AIR TEMPERATURE -- 22.53 DEGREES CELCIUS				
46	0.0	200.0	53.075	19.644	0.045	24.00	27.08	123.40	27.2	0.7042	150.67	71869.7
47	0.0	200.0	53.096	19.632	0.065	24.10	27.06	123.30	27.2	0.7038	150.66	71811.3
48	0.0	200.0	53.058	19.746	0.056	24.00	27.08	123.30	27.2	0.7079	150.29	71891.8
49	0.0	200.0	53.055	19.658	0.075	24.00	27.08	123.30	27.2	0.7047	150.66	71895.8
50	0.0	200.0	53.064	19.710	0.034	24.00	27.08	123.40	27.2	0.7066	150.42	71883.6
HAND. FLUID -- HG				BAROMETER -- 74.98 CM OF MERCURY				AIR TEMPERATURE -- 23.24 DEGREES CELCIUS				
51	119.5	1124.0	132.111	5.665	0.015	22.50	26.20	114.00	54.9	2.5793	150.67	142450.0
52	120.4	1123.0	131.746	5.695	0.000	22.70	26.25	114.00	54.9	2.5927	150.38	142719.0
53	119.2	1123.0	132.090	5.697	0.012	22.80	26.25	114.00	54.8	2.5936	150.15	142529.0
54	120.4	1125.0	132.295	5.719	0.024	22.90	23.29	114.00	54.8	2.6035	149.61	133958.0
55	120.5	1123.0	132.135	5.736	0.013	23.00	26.23	114.00	54.7	2.6114	149.34	142372.0



AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 1.25A

DATE 1/11/80 OBSERVERS - JM JH

AVE. INNER DIA. - 1.3813 INCHES; TAP SEPARATION - 17.833 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	27.5	0.14	0.699	.0056	153.03	0.13	5.89	0.0187	72089
2	35.0	0.11	1.102	.0008	152.22	0.46	7.49	0.0182	92005
3	42.3	0.02	1.573	.0013	151.84	0.14	9.06	0.0178	111216
4	47.7	0.01	1.959	.0033	151.86	0.15	10.20	0.0174	125264
5	55.1	0.02	2.599	.0035	150.83	0.10	11.81	0.0173	144937
6	55.5	0.06	2.641	.0025	150.36	0.19	11.87	0.0174	145769
7	47.8	0.03	1.983	.0029	151.29	0.18	10.23	0.0176	125934
8	41.8	0.01	1.558	.0017	150.60	0.12	8.94	0.0181	110338
9	34.1	0.03	1.070	.0017	150.76	0.14	7.30	0.0186	90140
10	27.2	0.01	0.705	.0017	150.54	0.17	5.82	0.0193	71870
11	54.8	0.07	2.596	.0121	150.03	0.55	11.74	0.0175	140805

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1.25R

DATE 1/11/30

OBSERVERS - JM &amp; JJ

AVE. INNER DIA. - 1.3892 INCHES; TAP SEPARATION - 17.572 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	MANOMETER HEIGHT (INCH)	MANOMETER STD. DEV. (INCH)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
MANO. FLUID -- WATER      BAROMETER -- 75.71 CM OF MERCURY      AIR TEMPERATURE -- 20.09 DEGREES CELCIUS												
1	0.0	200.0	54.557	19.112	0.274	21.70	25.83	112.00	26.5	0.6859	145.26	67777.8
2	0.0	200.0	54.607	18.946	0.084	21.70	25.83	112.00	26.4	0.6799	145.81	67715.7
3	0.0	200.0	54.663	19.048	0.163	21.65	25.83	112.20	26.4	0.6836	145.24	67646.3
4	0.0	200.0	54.657	18.938	0.061	21.70	25.83	112.20	26.4	0.6796	145.71	67653.7
5	0.0	200.0	54.650	18.990	0.066	21.65	25.83	112.20	26.4	0.6815	145.51	67662.4
MANO. FLUID -- WATER      BAROMETER -- 75.71 CM OF MERCURY      AIR TEMPERATURE -- 20.17 DEGREES CELCIUS												
6	0.0	200.0	42.603	30.650	0.061	21.55	25.83	121.70	33.9	1.0995	144.13	86795.5
7	0.0	200.0	42.617	30.593	0.133	21.45	25.83	121.70	33.9	1.0975	144.23	86767.0
8	0.0	200.0	42.616	30.515	0.009	21.45	25.83	121.70	33.9	1.0947	144.43	86769.0
9	0.0	200.0	42.627	30.523	0.072	21.40	25.83	121.70	33.9	1.0950	144.37	86746.6
10	0.0	200.0	42.673	30.485	0.040	21.40	25.83	121.70	33.8	1.0936	144.31	86653.1
MANO. FLUID -- WATER      BAROMETER -- 75.7 CM OF MERCURY      AIR TEMPERATURE -- 20.24 DEGREES CELCIUS												
11	0.0	200.0	35.550	43.460	0.022	21.40	25.83	120.80	40.6	1.5591	143.01	104015.0
12	0.0	200.0	35.632	43.240	0.062	21.40	25.83	120.80	40.5	1.5512	143.07	103782.0
13	0.0	200.0	35.694	43.178	0.038	21.40	25.83	120.80	40.4	1.5490	142.94	103596.0
14	0.0	200.0	35.726	43.168	0.042	21.40	25.83	120.80	40.4	1.5486	142.83	103503.0
15	0.0	200.0	35.723	43.188	0.139	21.40	25.83	120.80	40.4	1.5494	142.80	103512.0
MANO. FLUID -- HG      BAROMETER -- 75.69 CM OF MERCURY      AIR TEMPERATURE -- 20.33 DEGREES CELCIUS												
16	0.0	200.0	31.804	4.204	0.018	20.20	25.83	121.00	45.4	1.9144	143.07	116267.0
17	0.0	200.0	31.632	4.199	0.015	20.20	25.83	121.00	45.6	1.9121	143.94	116899.0
18	0.0	200.0	31.826	4.198	0.015	20.20	25.83	121.00	45.3	1.9118	143.07	116186.0
19	0.0	200.0	31.841	4.201	0.010	20.15	25.83	121.00	45.3	1.9129	142.96	116132.0
20	0.0	200.0	31.868	4.185	0.019	20.10	25.83	121.00	45.3	1.9057	143.13	116033.0
MANO. FLUID -- HG      BAROMETER -- 75.71 CM OF MERCURY      AIR TEMPERATURE -- 20.09 DEGREES CELCIUS												
21	0.0	200.0	27.340	5.695	0.021	20.05	25.83	121.00	52.8	2.5933	141.24	135251.0
22	0.0	200.0	27.341	5.690	0.031	20.10	25.83	121.00	52.8	2.5910	141.30	135246.0
23	0.0	200.0	27.354	5.674	0.034	20.00	25.83	121.00	52.8	2.5838	141.45	135181.0
24	0.0	200.0	27.346	5.673	0.026	20.10	25.83	121.00	52.8	2.5833	141.51	135221.0
25	0.0	200.0	27.341	5.696	0.024	20.10	25.83	121.00	52.8	2.5938	141.22	135246.0
MANO. FLUID -- HG      BAROMETER -- 75.65 CM OF MERCURY      AIR TEMPERATURE -- 20.98 DEGREES CELCIUS												
26	0.0	200.0	27.059	5.800	0.035	20.40	26.67	121.00	53.3	2.6410	141.34	139010.0
27	0.0	200.0	27.058	5.803	0.014	20.40	26.67	121.00	53.3	2.6424	141.31	139015.0
28	0.0	200.0	27.024	5.821	0.026	20.40	26.67	121.00	53.4	2.6506	141.25	139190.0
29	0.0	200.0	27.071	5.821	0.036	20.40	26.67	121.00	53.3	2.6506	141.00	138948.0
30	0.0	200.0	27.084	5.816	0.024	20.40	26.67	121.00	53.3	2.6481	141.01	138882.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1.25B

DATE 1/11/80

OBSERVERS - JM &amp; JH

AVE. INNER DIA. - 1.3892 INCHES; TAP SEPARATION - 17.572 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	---- MANOMETER HEIGHT (INCH)	---- STD. DEV. (INCH)	WATER TEMP. (DEG C)	STATIC TEMP. (DEG C)	PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER
MANO. FLUID -- HG				BAROMETER -- 75.65		CM OF MERCURY		AIR TEMPERATURE -- 21.12		DEGREES CELCIUS		
31	0.0	200.0	31.572	4.287	0.017	20.50	26.67	121.00	45.7	1.9517	142.64	119139.0
32	0.0	200.0	31.566	4.273	0.020	20.50	26.67	121.00	45.7	1.9455	142.93	119162.0
33	0.0	200.0	31.575	4.286	0.016	20.50	26.67	121.00	45.7	1.9515	142.65	119128.0
34	0.0	200.0	31.554	4.293	0.010	20.60	26.67	121.00	45.7	1.9549	142.61	119207.0
35	0.0	200.0	31.584	4.285	0.016	20.60	26.67	121.00	45.7	1.9511	142.62	119094.0
MANO. FLUID -- WATER				BAROMETER -- 75.64		CM OF MERCURY		AIR TEMPERATURE -- 20.23		DEGREES CELCIUS		
36	0.0	200.0	35.532	43.725	0.018	21.90	26.67	120.80	40.6	1.5685	142.65	105862.0
37	0.0	200.0	35.546	43.630	0.054	21.90	26.67	120.80	40.6	1.5651	142.77	105820.0
38	0.0	200.0	35.530	43.690	0.052	21.95	26.67	120.60	40.6	1.5672	142.72	105838.0
39	0.0	200.0	35.546	43.595	0.063	22.00	26.67	120.80	40.6	1.5638	142.83	105820.0
40	0.0	200.0	35.559	43.690	0.067	22.00	26.67	120.80	40.6	1.5672	142.61	105782.0
MANO. FLUID -- WATER				BAROMETER -- 75.63		CM OF MERCURY		AIR TEMPERATURE -- 21.36		DEGREES CELCIUS		
41	0.0	200.0	42.638	30.698	0.051	22.20	26.67	121.70	33.9	1.1010	143.94	88218.6
42	0.0	200.0	42.693	30.673	0.027	22.30	26.67	121.70	33.8	1.1001	143.82	88105.0
43	0.0	200.0	42.565	30.915	0.097	22.30	26.67	121.70	33.9	1.1098	143.64	88369.9
44	0.0	200.0	42.538	30.920	0.059	22.30	26.67	121.70	33.9	1.1090	143.71	88426.0
45	0.0	200.0	42.554	30.943	0.056	22.40	26.67	121.70	33.9	1.1098	143.61	88392.8
MANO. FLUID -- WATER				BAROMETER -- 75.61		CM OF MERCURY		AIR TEMPERATURE -- 21.46		DEGREES CELCIUS		
46	0.0	200.0	53.862	19.784	0.087	22.45	26.67	122.60	26.8	0.7095	144.49	69335.2
47	0.0	200.0	53.859	19.738	0.076	22.45	26.67	122.60	26.8	0.7079	144.68	69339.1
48	0.0	200.0	53.883	19.736	0.058	22.55	26.67	122.60	26.8	0.7078	144.62	69308.0
49	0.0	200.0	53.889	19.764	0.036	22.55	26.67	122.60	26.8	0.7088	144.50	69300.2
50	0.0	200.0	53.873	19.810	0.074	22.60	26.67	122.60	26.8	0.7104	144.36	69320.9

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 1.25B  
 DATE 1/11/80      OBSERVERS - JM & JH  
 AVE. INNER DIA. - 1.3892 INCHES; TAP SEPARATION - 17.572 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	26.4	0.02	0.682	.0026	145.51	0.26	5.59	0.0206	67691
2	33.9	0.02	1.096	.0024	144.30	0.12	7.17	0.0202	86746
3	40.5	0.08	1.551	.0044	142.93	0.12	8.56	0.0200	103682
4	45.4	0.13	1.911	.0033	143.23	0.40	9.61	0.0196	116303
5	52.8	0.01	2.589	.0051	141.35	0.13	11.17	0.0196	135229
6	53.3	0.04	2.647	.0046	141.18	0.16	11.29	0.0196	139009
7	45.7	0.02	1.951	.0034	142.69	0.13	9.68	0.0197	119146
8	40.6	0.01	1.566	.0019	142.72	0.09	8.60	0.0201	105830
9	33.9	0.05	1.106	.0047	143.74	0.14	7.17	0.0203	88302
10	26.8	0.01	0.709	.0011	144.53	0.13	5.67	0.0209	69821

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1.58

DATE JAN 4 89

OBSERVERS - JH &amp; MH

AVE. INNER DIA. - 1.6238 INCHES; TAP SEPARATION - 17.177 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	---- MANOMETER HEIGHT (INCH)	---- STD. DEV. (INCH)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER
HAND. FLUID -- WATER      BAROMETER -- 75.75 CM OF MERCURY      AIR TEMPERATURE -- 21.43 DEGREES CELCIUS											
1	120.3	920.3	97.498	35.423	0.044	22.50	120.80	59.2	1.2705	152.53	127517.0
2	120.3	919.3	97.503	35.379	0.047	22.60	120.80	59.1	1.2689	152.49	127429.0
3	120.5	918.8	97.460	35.334	0.052	22.65	121.20	59.1	1.2672	152.53	127374.0
4	120.8	918.2	97.460	35.306	0.059	22.60	120.90	59.0	1.2663	152.42	127309.0
5	120.5	919.8	97.672	35.280	0.039	22.70	121.00	59.0	1.2653	152.52	127440.0
HAND. FLUID -- WATER      BAROMETER -- 75.74 CM OF MERCURY      AIR TEMPERATURE -- 21.75 DEGREES CELCIUS											
6	120.0	916.0	83.676	46.796	0.276	22.65	121.10	68.6	1.6783	152.19	148264.0
7	120.1	922.7	84.562	46.714	0.105	22.60	121.40	68.5	1.6754	151.99	147988.0
8	119.5	921.1	84.124	47.137	0.276	22.70	121.60	68.7	1.6905	151.85	148696.0
9	120.2	924.0	84.167	47.286	0.069	22.75	121.60	68.9	1.6958	151.93	148977.0
10	119.8	921.7	84.350	46.908	0.065	22.80	121.70	68.6	1.6823	151.90	148414.0
HAND. FLUID -- WATER      BAROMETER -- 75.67 CM OF MERCURY      AIR TEMPERATURE -- 21.96 DEGREES CELCIUS											
11	120.4	921.8	76.020	57.002	0.076	22.80	120.60	76.1	2.0443	151.60	164709.0
12	120.2	920.8	75.951	57.100	0.052	22.80	120.70	76.0	2.0478	151.44	164762.0
13	120.5	921.8	76.075	57.093	0.039	22.90	121.30	76.0	2.0475	151.34	164671.0
14	120.0	922.0	76.442	56.442	0.162	23.00	120.90	75.7	2.0241	151.69	163990.0
15	120.3	922.2	76.737	56.257	0.059	23.00	120.90	75.4	2.0175	151.35	163540.0
HAND. FLUID -- WATER      BAROMETER -- 75.4 CM OF MERCURY      AIR TEMPERATURE -- 22.35 DEGREES CELCIUS											
16	119.4	922.6	76.399	56.738	0.244	23.15	120.90	75.8	2.0347	151.57	164394.0
17	120.7	922.1	75.876	57.333	0.108	23.20	119.40	76.2	2.0561	151.38	165350.0
18	120.4	921.1	75.849	57.305	0.019	23.20	119.50	76.2	2.0551	151.38	165444.0
19	120.6	921.3	75.938	57.193	0.079	23.20	119.50	76.1	2.0511	151.36	165318.0
20	120.6	922.5	76.018	57.187	0.034	23.40	119.40	76.1	2.0508	151.44	165459.0
HAND. FLUID -- WATER      BAROMETER -- 75.41 CM OF MERCURY      AIR TEMPERATURE -- 22.52 DEGREES CELCIUS											
21	120.6	918.8	84.816	46.147	0.063	23.40	118.40	67.9	1.6550	151.72	147794.0
22	120.2	922.3	85.256	46.117	0.084	23.40	118.40	67.9	1.6539	151.72	147780.0
23	121.0	920.4	84.349	46.820	0.094	23.40	117.70	68.4	1.6791	151.59	148927.0
24	120.2	920.1	84.641	46.553	0.208	23.45	122.20	68.2	1.6692	151.65	148536.0
25	120.3	918.6	84.578	46.464	0.105	23.50	117.40	68.1	1.6664	151.60	148593.0
HAND. FLUID -- WATER      BAROMETER -- 75.4 CM OF MERCURY      AIR TEMPERATURE -- 22.7 DEGREES CELCIUS											
26	120.2	920.8	94.710	37.783	0.077	23.60	117.80	61.0	1.3550	151.84	133106.0
27	120.4	920.2	94.945	37.553	0.066	23.60	118.00	60.8	1.3467	151.81	132698.0
28	120.1	920.1	93.435	38.447	0.347	23.60	121.30	61.8	1.3786	152.37	134932.0
29	120.0	920.2	94.345	38.817	0.110	23.75	121.30	61.2	1.3918	152.16	133746.0
30	120.0	920.5	93.410	38.890	0.052	23.80	121.30	61.8	1.3940	151.59	135135.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1.5B

DATE JAN 4 80

OBSERVERS - JH &amp; KH

AVE. INNER DIA. - 1.6238 INCHES; TAP SEPARATION - 17.177 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	---- MANOMETER HEIGHT (INCH)	---- STD. DEV. (INCH)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
MANO. FLUID -- HG				BAROMETER -- 74.84		CM OF MERCURY	AIR TEMPERATURE -- 20.3		DEGREES CELCIUS			
31	121.7	1118.0	94.948	4.557	0.026	20.35	24.38	120.00	75.7	2.0748	149.66	161091.0
32	120.8	1119.0	95.226	4.556	0.025	20.45	24.39	120.00	75.6	2.0746	149.52	160961.0
33	120.7	1117.0	95.195	4.555	0.027	20.40	24.41	120.00	75.5	2.0741	149.30	160773.0
34	117.1	1114.0	95.230	4.568	0.040	20.50	24.45	120.00	75.5	2.0798	149.11	160945.0
35	114.2	1111.0	95.171	4.558	0.031	20.70	24.46	120.00	75.5	2.0754	149.36	161062.0
MANO. FLUID -- HG				BAROMETER -- 74.81		CM OF MERCURY	AIR TEMPERATURE -- 20.59		DEGREES CELCIUS			
36	118.9	1315.0	82.910	8.398	0.039	20.90	24.53	120.00	104.1	3.8239	147.86	222167.0
37	120.7	1336.0	83.442	8.560	0.028	20.95	24.56	120.00	104.9	3.8976	147.57	224168.0
38	122.8	1322.0	82.131	8.613	0.027	20.95	24.55	120.00	105.3	3.9218	147.62	224948.0
39	120.9	1327.0	82.873	8.561	0.020	21.05	24.60	120.00	105.0	3.8978	147.63	224449.0
40	121.0	1325.0	85.527	8.603	0.020	21.05	24.63	120.00	101.5	3.9172	142.42	217240.0
MANO. FLUID -- HG				BAROMETER -- 74.62		CM OF MERCURY	AIR TEMPERATURE -- 21.27		DEGREES CELCIUS			
41	116.0	1318.0	86.539	7.836	0.194	21.60	24.60	120.00	100.2	3.5677	147.80	214209.0
42	116.6	1326.0	87.671	7.742	0.020	21.60	24.64	120.00	99.5	3.5250	147.75	212921.0
43	118.6	1321.0	87.089	7.770	0.017	21.60	24.68	120.00	99.6	3.5375	147.59	213280.0
44	118.3	1321.0	87.165	7.777	0.022	21.70	24.69	120.00	99.5	3.5407	147.43	213191.0
45	121.7	1320.0	86.952	7.756	0.020	21.70	24.76	120.00	99.4	3.5313	147.46	213249.0
MANO. FLUID -- HG				BAROMETER -- 21.42		CM OF MERCURY	AIR TEMPERATURE -- 21.42		DEGREES CELCIUS			
46	118.6	1118.0	93.824	4.736	0.016	21.70	24.75	120.00	76.8	2.1563	148.68	164647.0
47	118.5	1117.0	93.787	4.739	0.017	21.75	24.80	120.00	76.7	2.1575	148.56	164733.0
48	119.5	1118.0	93.765	4.734	0.019	21.80	24.82	120.00	76.7	2.1555	148.67	164840.0
49	118.4	1119.0	94.247	4.697	0.027	21.80	24.84	120.00	76.5	2.1393	148.87	164410.0
50	118.0	1117.0	94.134	4.712	0.013	21.80	24.81	120.00	76.5	2.1454	148.54	164242.0
MANO. FLUID -- WATER				BAROMETER -- 75.66		CM OF MERCURY	AIR TEMPERATURE -- 21.83		DEGREES CELCIUS			
51	0.0	200.0	30.777	24.128	0.088	22.40	25.28	120.00	46.9	0.8654	148.72	101636.0
52	0.0	200.0	31.047	23.920	0.234	22.60	25.28	120.20	46.5	0.8579	148.12	100752.0
53	0.0	200.0	31.417	23.183	0.032	22.60	25.28	120.20	45.9	0.8315	148.88	99565.1
54	0.0	200.0	30.752	24.148	0.028	22.60	25.28	120.20	46.9	0.8661	148.78	101718.0
55	0.0	200.0	30.795	24.058	0.040	22.70	25.28	120.20	46.9	0.8628	148.88	101576.0
MANO. FLUID -- WATER				BAROMETER -- 75.66		CM OF MERCURY	AIR TEMPERATURE -- 21.81		DEGREES CELCIUS			
56	0.0	200.0	39.526	15.045	0.049	22.80	25.28	121.20	36.5	0.5396	149.50	79138.8
57	0.0	200.0	39.654	14.888	0.035	22.80	25.28	121.20	36.4	0.5339	149.86	78933.3
58	0.0	200.0	39.586	14.900	0.034	22.85	25.28	121.10	36.4	0.5344	150.05	79018.8
59	0.0	200.0	39.599	14.892	0.101	22.90	25.28	121.20	36.4	0.5341	150.05	78992.9
60	0.0	200.0	39.621	14.898	0.034	22.90	25.28	121.20	36.4	0.5339	149.99	78949.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1.5B

DATE JAN 4 80

OBSERVERS - JH &amp; MH

AVE. INNER DIA. - 1.6238 INCHES; TAP SEPARATION - 17.177 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	---- MANOMETER HEIGHT (INCH)	---- STD. DEV. (DEG C)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
HAND. FLUID -- WATER			BAROMETER -- 75.59			CM OF MERCURY			AIR TEMPERATURE -- 22.33 DEGREES CELSIUS			
61	0.0	200.0	39.272	15.163	0.074	23.20	25.28	121.70	36.7	0.5437	149.84	79650.3
62	0.0	200.0	39.266	15.150	0.119	23.25	25.28	121.70	36.7	0.5433	149.93	79662.5
63	0.0	200.0	39.253	15.252	0.054	23.30	25.28	121.70	36.8	0.5469	149.44	79688.9
64	0.0	200.0	39.271	15.226	0.103	23.35	25.28	121.70	36.7	0.5460	149.51	79652.3
65	0.0	200.0	39.272	15.236	0.090	23.40	25.28	121.70	36.7	0.5463	149.45	79650.3

HAND. FLUID -- WATER			BAROMETER -- 75.59			CM OF MERCURY			AIR TEMPERATURE -- 22.37 DEGREES CELSIUS			
66	0.0	200.0	30.675	24.255	0.086	23.45	25.28	120.60	47.0	0.8698	148.81	101973.0
67	0.0	200.0	30.665	24.260	0.09	23.45	25.28	120.60	47.1	0.8699	148.85	102006.0
68	0.0	200.0	30.683	24.245	0.057	23.55	25.28	120.60	47.0	0.8694	148.81	101947.0
69	0.0	200.0	30.667	24.213	0.062	23.55	25.28	120.60	47.0	0.8682	149.00	102000.0
70	0.0	200.0	30.677	24.258	0.048	23.55	25.28	120.60	47.0	0.8698	148.80	101967.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 1.5B

DATE JAN 4 80

OBSERVERS - JH &amp; MH

AVE. INNER DIA. - 1.6238 INCHES; TAP SEPARATION - 17.177 FEET

GROUP NO.	FLOWRATE (GPM)		DIFF. PRESS. (PSI)		HAZEN-WILLIAMS MEAN		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.			
1	59.1	0.07	1.268	.0021	152.51	0.06	9.15	0.0172	127414
2	68.7	0.16	1.694	.0085	151.97	0.13	10.64	0.0169	148472
3	75.8	0.29	2.036	.0144	151.48	0.15	11.75	0.0167	164334
4	76.1	0.13	2.050	.0086	151.43	0.09	11.79	0.0168	165193
5	68.1	0.21	1.665	.0105	151.66	0.06	10.55	0.0170	148326
6	61.3	0.47	1.373	.0215	151.55	0.83	9.50	0.0173	133924
7	75.6	0.08	2.076	.0023	149.39	0.21	11.71	0.0172	160966
8	104.2	1.54	3.892	.0395	146.62	2.35	16.14	0.0170	222594
9	99.6	0.31	3.540	.0164	147.60	0.16	15.44	0.0169	213368
10	76.6	0.14	2.151	.0084	148.66	0.13	11.88	0.0173	164574
11	46.6	0.42	0.857	.0145	148.68	0.32	7.22	0.0186	101049
12	36.4	0.04	0.535	.0025	149.89	0.23	5.65	0.0191	78997
13	36.7	0.01	0.545	.0016	149.63	0.23	5.69	0.0191	79661
14	47.0	0.01	0.869	.0007	148.85	0.08	7.29	0.0186	101979

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 2A

DATE 12/28-31/77

OBSERVERS - JH VB

AVE. INNER DIA. - 2.0665 INCHES; TAP SEPARATION - 16.395 FEET

RUN NO. (RH)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	---- MANOMETER HEIGHT (INCH)	---- STD. DEV. (INCH)	WATER TEMP. (DEG C)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER
HAND. FLUID -- WATER      BAROMETER -- 75.82 CM OF MERCURY      AIR TEMPERATURE -- 21 DEGREES CELCIUS												
1	121.1	915.7	92.728	11.479	0.115	23.15	24.46	122.40	61.8	0.4116	151.41	103545.0
2	121.0	914.9	92.530	11.481	0.065	23.00	24.53	122.20	61.9	0.4117	151.59	103926.0
3	120.9	916.5	92.659	11.551	0.054	22.90	24.54	122.30	61.9	0.4142	151.20	103925.0
4	120.9	915.0	92.529	11.558	0.074	22.80	24.60	122.30	61.9	0.4145	151.02	104004.0
5	121.0	915.1	92.525	11.588	0.060	22.80	24.63	122.40	61.9	0.4155	150.89	104073.0
HAND. FLUID -- WATER      BAROMETER -- 75.81 CM OF MERCURY      AIR TEMPERATURE -- 21.36 DEGREES CELCIUS												
6	120.9	1113.0	94.960	16.974	0.049	22.90	24.70	121.10	75.4	0.6087	149.42	126871.0
7	121.2	1112.0	94.707	17.029	0.059	22.90	24.65	121.00	75.5	0.6107	149.36	126912.0
8	121.1	1111.0	94.605	17.070	0.051	22.90	24.75	121.10	75.5	0.6122	149.20	127196.0
9	120.5	1119.0	94.658	17.416	0.109	22.90	24.79	121.30	76.1	0.6246	148.79	128336.0
10	120.9	1117.0	94.594	17.360	0.041	23.00	24.82	121.30	76.0	0.6226	148.79	128193.0
HAND. FLUID -- WATER      BAROMETER -- 75.82 CM OF MERCURY      AIR TEMPERATURE -- 21.67 DEGREES CELCIUS												
11	120.4	1121.0	80.711	23.850	0.035	22.85	24.85	120.00	89.4	0.8554	147.53	151016.0
12	121.1	1115.0	80.469	23.745	0.023	23.00	24.88	120.20	89.1	0.8516	147.34	150549.0
13	120.9	1316.0	96.812	23.784	0.059	23.10	24.91	120.50	89.0	0.8529	147.13	150559.0
14	120.9	1314.0	96.815	23.776	0.037	23.05	24.94	120.60	88.9	0.8527	146.91	150396.0
15	121.0	1313.0	96.659	23.860	0.046	23.20	24.95	120.40	88.9	0.8557	146.72	150515.0
HAND. FLUID -- WATER      BAROMETER -- 75.8 CM OF MERCURY      AIR TEMPERATURE -- 21.95 DEGREES CELCIUS												
16	121.1	1518.0	95.851	32.947	0.057	23.15	24.98	119.20	105.1	1.1816	145.65	178933.0
17	120.9	1513.0	95.516	33.011	0.063	23.25	25.02	119.40	105.1	1.1839	145.51	178160.0
18	121.0	1517.0	95.556	33.294	0.054	23.40	25.06	119.30	105.4	1.1940	145.19	178732.0
19	120.7	1514.0	95.594	33.196	0.073	23.40	25.06	119.60	105.1	1.1904	145.08	178315.0
20	121.0	1516.0	95.491	33.367	0.036	23.40	25.11	119.40	105.4	1.1966	145.01	178909.0
HAND. FLUID -- WATER      BAROMETER -- 75.68 CM OF MERCURY      AIR TEMPERATURE -- 23.02 DEGREES CELCIUS												
21	120.7	1720.0	96.512	42.754	0.082	23.60	25.13	120.50	119.5	1.5331	143.87	203023.0
22	120.9	1720.0	96.674	42.716	0.049	23.75	25.15	120.30	119.3	1.5317	143.68	202741.0
23	120.8	1717.0	96.454	42.863	0.055	23.80	25.19	120.30	119.4	1.5369	143.48	203092.0
24	120.9	1714.0	96.421	42.866	0.031	23.85	25.21	119.80	119.2	1.5370	143.25	202761.0
25	121.1	1719.0	96.485	43.146	0.166	23.85	25.24	120.80	119.5	1.5470	143.03	203362.0
HAND. FLUID -- WATER      BAROMETER -- 75.67 CM OF MERCURY      AIR TEMPERATURE -- 23.12 DEGREES CELCIUS												
26	120.8	1922.0	95.924	55.624	0.067	23.90	25.30	121.20	135.5	1.9944	141.42	239361.0
27	120.8	1930.0	96.501	55.599	0.065	23.85	25.31	121.70	135.3	1.9934	141.24	239547.0
28	121.2	1922.0	95.918	55.891	0.059	23.85	25.33	121.40	135.4	2.0039	141.03	239966.0
29	120.9	1918.0	96.879	55.888	0.055	23.90	25.38	122.30	133.8	2.0037	139.36	228440.0
30	121.1	1911.0	95.891	55.549	0.047	23.85	25.40	121.70	134.7	1.9916	140.69	229963.0



## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 2A

DATE 12/28-31/77

OBSERVERS - JH VB

AVE. INNER DIA. - 2.0665 INCHES; TAP SEPARATION - 16.385 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	---- MANDMETER HEIGHT (INCH)	---- STD. DEV. (REV.)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
MAND. FLUID -- WATER				BAROMETER -- 75.03		CM OF MERCURY	AIR TEMPERATURE -- 20.75		DEGREES CELCIUS			
31	118.7	1921.0	97.568	55.156	0.111	21.60	24.15	105.50	133.2	1.9799	139.63	221773.0
32	121.0	1919.0	97.548	55.038	0.081	21.60	24.18	105.50	132.9	1.9757	139.49	221428.0
33	121.2	1919.0	97.438	55.412	0.134	21.70	24.21	105.50	133.1	1.9891	139.12	221791.0
34	121.1	1918.0	97.416	55.652	0.073	21.75	24.24	105.60	133.0	1.9977	139.76	221869.0
35	121.0	1911.0	97.435	55.430	0.107	21.85	24.28	105.60	132.5	1.9897	138.50	221157.0
MAND. FLUID -- WATER				BAROMETER -- 75.05		CM OF MERCURY	AIR TEMPERATURE -- 21.39		DEGREES CELCIUS			
36	121.1	1721.0	98.772	43.022	0.113	22.15	24.31	105.60	116.8	1.5442	140.05	195116.0
37	121.3	1710.0	98.531	42.908	0.086	22.15	24.35	105.70	116.3	1.5401	139.61	194385.0
38	121.2	1704.0	98.547	42.622	0.069	22.20	24.38	105.70	115.8	1.5298	139.58	193752.0
39	120.9	1705.0	98.415	43.038	0.156	22.30	24.41	105.70	115.9	1.5465	138.89	194047.0
40	121.0	1706.0	98.493	43.180	0.101	22.40	24.46	105.80	116.1	1.5497	138.87	194451.0
MAND. FLUID -- WATER				BAROMETER -- 75.05		CM OF MERCURY	AIR TEMPERATURE -- 21.72		DEGREES CELCIUS			
41	120.3	1517.0	99.040	33.420	0.092	22.60	24.49	105.70	101.7	1.1994	139.78	170509.0
42	120.9	1521.0	99.469	33.470	0.033	22.60	24.51	105.80	101.5	1.2012	139.41	170257.0
43	121.1	1495.0	99.478	32.380	0.056	22.60	24.52	105.80	99.6	1.1621	139.26	167091.0
44	121.1	1515.0	99.487	33.650	0.144	22.70	24.53	105.80	101.1	1.2076	138.37	169543.0
45	121.0	1518.0	99.502	33.866	0.122	22.90	24.56	105.90	101.3	1.2153	138.18	170090.0
MAND. FLUID -- WATER				BAROMETER -- 75.05		CM OF MERCURY	AIR TEMPERATURE -- 22.02		DEGREES CELCIUS			
46	120.7	1316.0	100.550	24.420	0.033	22.95	24.62	105.90	85.7	0.8763	139.62	144118.0
47	121.2	1322.0	100.510	24.734	0.162	23.05	24.64	105.90	86.2	0.8976	139.35	144897.0
48	121.1	1322.0	100.454	25.022	0.135	23.20	24.68	106.00	86.2	0.8979	138.58	145112.0
49	121.1	1306.0	100.438	24.510	0.068	23.25	24.69	106.00	85.1	0.8795	138.29	143231.0
50	121.2	1306.0	100.424	24.644	0.043	23.40	24.72	106.00	85.1	0.8343	137.90	143327.0
MAND. FLUID -- WATER				BAROMETER -- 75.03		CM OF MERCURY	AIR TEMPERATURE -- 22.3		DEGREES CELCIUS			
51	120.8	1115.0	101.371	17.288	0.060	23.50	24.74	106.00	70.7	0.6203	138.85	119196.0
52	121.0	1119.0	101.505	17.503	0.066	23.55	24.75	106.00	70.9	0.6280	138.26	119517.0
53	120.8	1121.0	101.405	17.577	0.099	23.55	24.79	106.00	71.1	0.6307	138.40	119999.0
54	121.0	1118.0	101.438	17.564	0.096	23.75	24.79	106.00	70.9	0.6302	137.97	119576.0
55	121.0	1115.0	101.450	17.637	0.096	23.75	24.81	106.00	70.7	0.6328	137.21	119240.0
MAND. FLUID -- WATER				BAROMETER -- 74.98		CM OF MERCURY	AIR TEMPERATURE -- 22.54		DEGREES CELCIUS			
56	120.8	915.5	105.592	10.697	0.128	23.80	24.82	106.00	54.3	0.3938	138.12	91620.0
57	121.1	916.4	105.472	10.698	0.196	23.80	24.85	106.00	54.4	0.3938	138.38	91850.3
58	120.9	920.8	105.504	10.772	0.113	23.80	24.86	106.00	54.7	0.3865	138.62	92372.6
59	120.9	920.7	105.486	10.838	0.098	23.90	24.87	106.00	54.7	0.3906	137.83	92395.9
60	121.0	918.4	105.482	10.840	0.034	24.00	24.88	106.00	54.5	0.3889	137.75	92141.2

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 2A  
 DATE 12/28-31/7 OBSERVERS - JH VB  
 AVE. INNER DIA. - 2.0665 INCHES; TAP SEPARATION - 16.385 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	61.9	0.05	0.414	.0018	151.23	0.28	5.92	0.0180	103874
2	75.7	0.33	0.616	.0073	149.11	0.31	7.24	0.0179	127502
3	89.1	0.21	0.854	.0018	147.13	0.33	8.52	0.0179	150607
4	105.2	0.14	1.189	.0064	145.28	0.28	10.07	0.0179	178424
5	119.4	0.13	1.537	.0060	143.47	0.32	11.42	0.0179	202978
6	134.9	0.70	1.997	.0059	140.75	0.82	12.91	0.0182	230155
7	133.0	0.27	1.986	.0087	139.10	0.47	12.72	0.0187	221604
8	116.2	0.39	1.542	.0077	139.40	0.51	11.11	0.0190	194350
9	101.0	0.83	1.197	.0206	139.00	0.69	9.66	0.0195	169480
10	85.7	0.55	0.885	.0083	138.75	0.72	8.19	0.0201	144137
11	70.9	0.18	0.628	.0048	138.14	0.61	6.78	0.0208	119505
12	54.5	0.18	0.387	.0030	138.14	0.37	5.22	0.0216	92076

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 2B

DATE 1/2/80

OBSERVERS - JH VB HJ

AVE. INNER DIA. - 2.0919 INCHES; TAP SEPARATION - 16.125 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	--- HANOMETER --- HEIGHT (INCH)	WATER STD. DEV. (DEG C)	TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER
HAND. FLUID -- WATER      BAROMETER -- 75.96 CM OF MERCURY      AIR TEMPERATURE -- 21.63 DEGREES CELCIUS											
1	120.8	1933.0	89.037	55.044	0.040	22.90	24.03	121.60	146.8	1.9740	147.93 240790.0
2	119.7	1932.0	89.197	54.937	0.044	22.95	24.02	121.50	146.5	1.9701	147.83 240622.0
3	120.5	1927.0	89.784	55.119	0.036	22.95	24.11	121.60	146.7	1.9766	147.79 241118.0
4	119.9	1930.0	89.114	55.051	0.062	22.90	24.15	121.50	146.5	1.9743	147.63 240905.0
5	120.6	1928.0	89.907	55.129	0.025	22.95	24.18	121.60	146.6	1.9770	147.64 241256.0
HAND. FLUID -- WATER      BAROMETER -- 74.96 CM OF MERCURY      AIR TEMPERATURE -- 21.76 DEGREES CELCIUS											
6	120.3	1926.0	102.426	41.916	0.051	23.00	24.23	119.90	127.1	1.5032	148.47 209430.0
7	120.5	1924.0	102.373	41.850	0.065	22.95	24.24	119.50	127.1	1.5037	148.49 209327.0
8	120.5	1926.0	102.434	41.978	0.047	23.05	24.23	119.60	127.1	1.5035	148.32 209609.0
9	120.2	1927.0	102.616	41.861	0.034	23.05	24.33	119.40	127.0	1.5013	148.39 209605.0
10	120.3	1922.0	102.274	42.023	0.042	23.05	24.34	119.40	127.1	1.5071	148.16 209756.0
HAND. FLUID -- WATER      BAROMETER -- 74.92 CM OF MERCURY      AIR TEMPERATURE -- 22.01 DEGREES CELCIUS											
11	120.8	1522.0	90.295	32.890	0.045	23.15	24.26	121.30	111.9	1.1794	149.00 184464.0
12	120.7	1526.0	90.493	32.980	0.076	23.20	24.30	121.30	112.0	1.1827	148.89 184752.0
13	120.8	1523.0	90.471	32.926	0.060	23.25	24.30	121.20	111.8	1.1807	148.73 184389.0
14	120.5	1524.0	90.411	33.060	0.063	23.35	24.33	121.30	112.0	1.1855	148.65 184990.0
15	120.7	1523.0	90.527	32.960	0.035	23.35	24.42	121.30	111.7	1.1819	148.57 184748.0
HAND. FLUID -- WATER      BAROMETER -- 74.92 CM OF MERCURY      AIR TEMPERATURE -- 22.05 DEGREES CELCIUS											
16	320.3	1518.0	91.053	24.159	0.127	23.25	24.45	115.60	94.9	0.8665	149.21 156979.0
17	320.8	1532.0	91.463	24.365	0.161	23.40	24.48	118.30	95.5	0.8738	149.54 158135.0
18	325.9	1530.0	91.442	24.409	0.072	23.40	24.49	118.30	95.0	0.8754	148.55 157277.0
19	321.9	1532.0	91.451	24.413	0.026	23.45	24.51	118.30	95.4	0.8755	149.27 158110.0
20	321.2	1532.0	91.441	24.473	0.023	23.45	24.55	118.30	95.5	0.8776	149.18 158350.0
HAND. FLUID -- WATER      BAROMETER -- 74.93 CM OF MERCURY      AIR TEMPERATURE -- 22.13 DEGREES CELCIUS											
21	321.5	1317.0	91.077	16.981	0.037	23.60	24.57	120.00	78.8	0.6089	150.04 130768.0
22	321.4	1319.0	91.461	16.931	0.030	23.60	24.58	120.00	78.7	0.6071	149.97 130520.0
23	321.8	1322.0	91.436	17.058	0.031	23.60	24.59	120.00	78.9	0.6117	149.80 130923.0
24	321.1	1311.0	91.417	16.784	0.263	23.60	24.62	120.00	78.1	0.6019	149.59 129682.0
25	321.4	1316.0	91.433	16.853	0.046	23.60	24.63	120.00	78.5	0.6047	149.89 130302.0
HAND. FLUID -- WATER      BAROMETER -- 74.94 CM OF MERCURY      AIR TEMPERATURE -- 22.12 DEGREES CELCIUS											
26	321.7	1115.0	90.765	11.123	0.041	23.65	24.65	121.50	63.0	0.3988	150.82 104758.0
27	321.0	1105.0	90.459	11.030	0.088	23.70	24.67	121.60	62.5	0.3955	150.24 103904.0
28	320.4	1103.0	90.547	10.931	0.032	23.75	24.67	121.60	62.3	0.3919	150.55 103617.0
29	321.4	1104.0	90.419	10.988	0.016	23.75	24.69	121.70	62.4	0.3940	150.35 103827.0
30	322.4	1103.0	90.483	10.932	0.044	23.70	24.71	121.60	62.2	0.3920	150.27 103511.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 28

DATE 1/2/60

OBSERVERS - JH VB KH

AVE. INNER DIA. - 2.0919 INCHES; TAP SEPARATION - 16.125 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	--- MANOMETER --- HEIGHT (INCH)	--- WATER STD. DEV. (DEG C)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
MANO. FLUID -- WATER      BAROMETER -- 75.53 CM OF MERCURY      AIR TEMPERATURE -- 21.52 DEGREES CELCIUS												
31	120.4	1529.0	90.104	34.047	0.055	22.80	24.31	122.40	112.8	1.2210	147.33	186026.0
32	120.1	1519.0	89.592	34.011	0.028	22.80	24.35	122.30	112.6	1.2197	147.23	185955.0
33	121.0	1514.0	89.318	33.989	0.037	22.70	24.37	122.30	112.5	1.2189	147.11	185816.0
34	120.4	1527.0	90.334	33.983	0.048	22.70	24.41	122.30	112.3	1.2187	146.87	185674.0
35	120.4	1526.0	90.316	33.991	0.031	22.70	24.44	122.30	112.3	1.2190	146.80	185695.0
MANO. FLUID -- WATER      BAROMETER -- 75.52 CM OF MERCURY      AIR TEMPERATURE -- 21.69 DEGREES CELCIUS												
36	120.1	1921.0	102.715	43.086	0.066	22.80	24.52	120.80	126.5	1.5452	145.47	205545.0
37	120.7	1927.0	103.097	43.070	0.056	22.80	24.54	121.10	126.4	1.5446	145.41	207482.0
38	120.4	1928.0	103.158	43.126	0.100	22.80	24.56	121.20	126.4	1.5467	145.33	205995.0
39	119.7	1928.0	103.154	43.196	0.068	22.80	24.65	121.20	126.4	1.5492	145.27	210076.0
40	120.5	1922.0	102.958	43.135	0.047	22.80	24.66	121.10	126.2	1.5470	145.11	209728.0
MANO. FLUID -- WATER      BAROMETER -- 75.43 CM OF MERCURY      AIR TEMPERATURE -- 22.66 DEGREES CELCIUS												
41	120.5	1921.0	89.915	56.152	0.065	23.20	24.64	121.90	144.4	2.0135	144.01	239917.0
42	119.4	1925.0	90.093	56.323	0.047	23.30	24.67	121.70	144.6	2.0197	143.90	240270.0
43	120.5	1915.0	89.675	56.216	0.062	23.35	24.72	121.80	144.3	2.0158	143.83	240154.0
44	120.3	1928.0	90.395	56.321	0.044	23.45	24.76	121.70	144.2	2.0195	143.59	240192.0
45	120.7	1925.0	90.147	56.310	0.076	23.50	24.78	121.80	144.4	2.0191	143.74	240499.0
MANO. FLUID -- WATER      BAROMETER -- 75.42 CM OF MERCURY      AIR TEMPERATURE -- 22.89 DEGREES CELCIUS												
46	120.6	1517.0	106.538	24.451	0.074	23.75	24.85	119.20	94.6	0.8768	147.80	157798.0
47	120.7	1521.0	107.023	24.440	0.031	23.80	24.89	119.50	94.4	0.8764	147.53	157575.0
48	120.3	1525.0	107.177	24.533	0.051	24.00	24.88	119.20	94.5	0.8797	147.48	157810.0
49	120.6	1524.0	107.294	24.533	0.062	24.05	24.96	119.20	94.4	0.8797	147.19	157752.0
50	120.6	1524.0	107.129	24.619	0.038	24.05	24.98	119.20	94.5	0.8827	147.14	158060.0
MANO. FLUID -- WATER      BAROMETER -- 75.44 CM OF MERCURY      AIR TEMPERATURE -- 23.07 DEGREES CELCIUS												
51	120.5	1320.0	110.053	17.260	0.124	24.20	25.05	117.50	78.6	0.6187	148.33	131696.0
52	120.6	1320.0	110.232	17.222	0.035	24.20	25.07	118.80	78.5	0.6175	148.26	131526.0
53	120.3	1320.0	110.584	17.142	0.032	24.30	25.10	119.00	78.3	0.6146	148.20	131221.0
54	120.9	1320.0	110.400	17.269	0.048	24.30	25.12	118.90	78.4	0.6192	147.78	131428.0
55	120.4	1318.0	110.450	17.307	0.057	24.35	25.13	119.00	78.2	0.6205	147.36	131231.0
MANO. FLUID -- WATER      BAROMETER -- 75.5 CM OF MERCURY      AIR TEMPERATURE -- 23.01 DEGREES CELCIUS												
56	120.7	1116.0	117.124	10.793	0.081	24.35	25.17	120.70	61.3	0.3869	149.07	102933.0
57	119.9	1118.0	120.959	10.152	0.094	24.25	25.18	119.60	59.5	0.3640	149.62	99970.8
58	120.6	1121.0	119.290	10.614	0.079	24.25	25.19	119.60	60.5	0.3806	148.45	101624.0
59	120.7	1117.0	118.446	10.693	0.058	24.25	25.23	119.30	60.7	0.3834	148.30	102013.0
60	120.5	1118.0	118.467	10.893	0.060	24.20	25.24	119.50	60.7	0.3873	147.63	102138.0

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 2B

DATE 1/2/80 OBSERVERS - JH VB MH

AVE. INNER DIA. - 2.0919 INCHES; TAP SEPARATION - 16.125 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	146.6	0.13	1.974	.0027	147.77	0.13	13.69	0.0165	240938
2	127.1	0.06	1.504	.0027	148.37	0.13	11.86	0.0167	209545
3	111.9	0.12	1.182	.0023	148.77	0.18	10.44	0.0170	184669
4	95.3	0.31	0.874	.0043	149.15	0.36	8.89	0.0173	157770
5	78.6	0.32	0.607	.0038	149.86	0.18	7.34	0.0177	130439
6	62.5	0.32	0.394	.0029	150.44	0.24	5.84	0.0181	103915
7	112.5	0.21	1.219	.0009	147.07	0.22	10.50	0.0173	185833
8	126.4	0.10	1.547	.0018	145.32	0.14	11.80	0.0174	209685
9	144.4	0.12	2.018	.0028	143.82	0.16	13.48	0.0174	240206
10	94.5	0.10	0.879	.0026	147.43	0.27	8.82	0.0177	157799
11	78.4	0.17	0.618	.0022	147.98	0.41	7.32	0.0181	131420
12	60.5	0.65	0.380	.0096	148.61	0.76	5.65	0.0186	101736

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 2.5A

DATE 12/19/79

OBSERVERS - JH VA

AVE. DIAMETER - 2.474 INCHES; TAP SEPARATION - 15.552 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	---- MANOMETER HEIGHT (INCH)	---- MANOMETER STD. DEV. (INCH)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
MANG. FLUID -- WATER      BAROMETER -- 75.26 CM OF MERCURY      AIR TEMPERATURE -- 21.2 DEGREES CELCIUS												
1	140.5	2123.0	172.701	7.706	0.162	22.65	24.25	121.20	82.8	0.2764	152.28	115358.0
2	152.4	2133.0	165.862	8.268	0.094	22.65	24.27	119.90	86.1	0.2965	152.48	120349.0
3	162.0	2122.0	164.068	8.314	0.140	22.55	24.30	121.00	86.2	0.2982	152.10	120175.0
4	141.5	2122.0	169.164	8.013	0.145	22.65	24.32	120.90	84.4	0.2874	152.06	117872.0
5	147.6	2122.0	171.333	7.823	0.117	22.80	24.35	121.00	83.1	0.2806	151.63	116045.0
MANG. FLUID -- WATER      BAROMETER -- 75.28 CM OF MERCURY      AIR TEMPERATURE -- 21.35 DEGREES CELCIUS												
6	150.7	2140.0	128.101	13.938	0.217	22.70	24.43	118.80	112.0	0.4999	149.53	156637.0
7	148.2	2124.0	128.636	13.821	0.183	22.70	24.44	118.70	110.8	0.4957	149.57	154961.0
8	156.8	2126.0	131.758	13.094	0.160	22.80	24.47	119.20	107.8	0.4696	148.86	150978.0
9	145.8	2126.0	131.382	13.317	0.165	22.80	24.51	119.10	108.7	0.4776	148.75	152281.0
10	147.2	2126.0	133.365	13.031	0.360	22.80	24.53	119.30	107.0	0.4674	148.17	149973.0
MANG. FLUID -- WATER      BAROMETER -- 75.32 CM OF MERCURY      AIR TEMPERATURE -- 21.5 DEGREES CELCIUS												
11	142.5	2131.0	109.932	18.876	0.164	22.80	24.56	120.50	130.5	0.6770	147.85	182946.0
12	145.0	2156.0	110.161	19.222	0.104	22.80	24.58	120.30	131.7	0.6894	147.76	184708.0
13	153.5	2149.0	110.470	18.922	0.076	22.80	24.59	120.60	130.3	0.6786	147.46	182810.0
14	145.7	2158.0	110.589	19.251	0.208	22.80	24.62	120.60	131.2	0.6904	147.16	184265.0
15	148.3	2169.0	111.157	19.196	0.090	22.80	24.63	120.40	131.1	0.6885	147.25	184138.0
MANG. FLUID -- WATER      BAROMETER -- 76.18 CM OF MERCURY      AIR TEMPERATURE -- 19.71 DEGREES CELCIUS												
16	143.9	3140.0	141.798	25.533	0.077	20.40	24.19	120.20	152.4	0.9162	146.64	212072.0
17	154.7	3138.0	143.131	24.931	0.049	20.55	24.20	120.70	150.3	0.8946	146.53	209243.0
18	146.8	3140.0	141.131	25.811	0.077	20.65	24.21	120.20	153.0	0.9261	146.33	212956.0
19	144.8	3139.0	139.332	26.506	0.337	20.80	24.24	120.20	155.0	0.9510	146.17	215913.0
20	146.4	3137.0	140.377	26.445	0.282	21.00	24.31	120.60	153.7	0.9488	145.09	214359.0
MANG. FLUID -- WATER      BAROMETER -- 76.26 CM OF MERCURY      AIR TEMPERATURE -- 20.13 DEGREES CELCIUS												
21	141.5	3148.0	107.988	44.245	0.160	20.85	24.39	119.20	200.8	1.5876	143.55	280599.0
22	146.9	3144.0	107.876	44.119	0.031	21.00	24.41	119.30	200.4	1.5830	143.48	280129.0
23	146.0	3138.0	107.908	43.949	0.135	21.15	24.47	119.60	200.0	1.5768	143.50	279917.0
24	147.2	3150.0	107.997	44.275	0.088	21.10	24.48	119.30	200.5	1.5886	143.32	280754.0
25	145.2	3141.0	108.597	43.700	0.069	21.25	24.49	119.50	199.0	1.5679	143.21	278610.0
MANG. FLUID -- WATER      BAROMETER -- 76.32 CM OF MERCURY      AIR TEMPERATURE -- 20.43 DEGREES CELCIUS												
26	144.2	3146.0	123.214	34.668	0.029	21.35	24.56	119.50	175.7	1.2438	143.34	246407.0
27	146.4	3167.0	123.888	34.760	0.036	21.40	24.59	119.30	176.0	1.2471	143.34	246914.0
28	145.2	3145.0	123.274	34.663	0.038	21.45	24.63	119.50	175.5	1.2436	143.19	246480.0
29	145.5	3158.0	123.687	34.736	0.031	21.45	24.65	119.40	175.7	1.2462	143.15	246799.0
30	145.2	3151.0	123.688	34.687	0.067	21.50	24.69	119.50	175.4	1.2444	143.04	246616.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 2.5A

DATE 12/19/79

OBSERVERS - JH VB

AVE. INNER DIA. - 2.474 INCHES; TAP SEPARATION - 15.552 FEET

RUN NO. (RN)	TARE WT (LB)	CROSS WT (LB)	DIVERT TIME (SEC)	---- MANOMETER HEIGH (INCH)	---- STD. DEV. (INCH)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
HAND. FLUID -- WATER      BAROMETER -- 75.37 CM OF MERCURY      AIR TEMPERATURE -- 21.48 DEGREES CELCIUS												
31	148.2	3148.0	103.716	44.210	0.131	22.75	24.29	119.50	208.6	1.5857	149.22	290896.0
32	149.4	3142.0	103.611	44.171	0.068	22.80	24.32	119.50	208.3	1.5842	149.09	290672.0
33	148.2	3155.0	103.574	44.664	0.083	22.55	24.36	119.40	209.4	1.6020	148.95	292399.0
34	147.3	3149.0	104.136	43.869	0.083	22.75	24.39	119.50	207.9	1.5734	149.34	290508.0
35	141.9	3149.0	103.910	44.376	0.084	22.80	24.42	119.50	208.7	1.5916	149.01	291846.0
HAND. FLUID -- WATER      BAROMETER -- 75.35 CM OF MERCURY      AIR TEMPERATURE -- 21.60 DEGREES CELCIUS												
36	148.6	3153.0	117.270	35.242	0.104	22.75	24.42	118.30	184.8	1.2641	149.41	258365.0
37	145.9	3153.0	117.890	34.787	0.051	22.80	24.46	118.50	184.0	1.2477	149.81	257450.0
38	142.8	3140.0	117.089	35.273	0.099	22.90	24.49	118.40	184.6	1.2651	149.22	258519.0
39	147.7	3143.0	117.416	34.873	0.149	22.90	24.50	118.50	184.0	1.2508	149.63	257689.0
40	147.4	3143.0	117.051	35.280	0.094	22.90	24.51	118.50	184.6	1.2654	149.17	258572.0
HAND. FLUID -- WATER      BAROMETER -- 75.31 CM OF MERCURY      AIR TEMPERATURE -- 22.49 DEGREES CELCIUS												
41	122.3	1926.0	84.921	25.098	0.044	23.25	24.60	120.40	153.2	0.9000	148.84	214996.0
42	122.0	1912.0	84.484	24.986	0.016	23.40	24.64	120.20	152.8	0.8960	148.83	214639.0
43	121.1	1911.0	84.496	25.048	0.041	23.40	24.67	120.40	152.8	0.8982	148.61	214735.0
44	121.2	1912.0	84.464	25.141	0.044	23.60	24.70	120.30	152.9	0.9015	148.45	215067.0
45	121.4	1910.0	84.438	25.130	0.030	23.70	24.75	120.30	152.8	0.9011	148.35	215082.0
HAND. FLUID -- WATER      BAROMETER -- 75.32 CM OF MERCURY      AIR TEMPERATURE -- 22.83 DEGREES CELCIUS												
46	121.0	1722.0	87.346	19.096	0.045	23.80	24.77	119.20	132.2	0.6847	148.91	186189.0
47	121.5	1725.0	87.452	19.153	0.027	23.80	24.81	119.50	132.3	0.6868	148.72	186406.0
48	121.0	1724.0	87.390	19.233	0.047	23.85	24.83	119.30	132.3	0.6896	148.45	186559.0
49	121.2	1726.0	87.445	19.276	0.049	24.00	24.87	119.80	132.4	0.6911	148.35	186805.0
50	121.1	1722.0	87.351	19.250	0.034	24.00	24.88	119.20	132.2	0.6902	148.25	186591.0
HAND. FLUID -- WATER      BAROMETER -- 75.33 CM OF MERCURY      AIR TEMPERATURE -- 23.04 DEGREES CELCIUS												
51	120.7	1522.0	91.083	13.828	0.026	24.00	24.92	121.10	111.0	0.4958	148.83	156764.0
52	121.3	1522.0	91.083	13.873	0.015	24.00	24.97	120.80	110.9	0.4974	148.50	156958.0
53	121.3	1517.0	90.729	13.887	0.028	24.15	25.00	121.20	111.0	0.4979	148.48	157045.0
54	121.3	1518.0	90.777	13.920	0.035	24.15	25.01	121.10	111.0	0.4991	148.31	157067.0
55	121.2	1517.0	90.739	13.956	0.027	24.20	25.04	121.30	111.0	0.5003	148.08	157129.0
HAND. FLUID -- WATER      BAROMETER -- 75.35 CM OF MERCURY      AIR TEMPERATURE -- 23.08 DEGREES CELCIUS												
56	120.9	1317.0	104.534	7.982	0.024	24.20	25.04	119.40	82.6	0.2852	149.02	116912.0
57	120.9	1324.0	104.507	8.065	0.037	24.20	25.10	119.40	83.0	0.2892	149.05	117739.0
58	120.7	1326.0	104.643	8.100	0.034	24.15	25.11	120.10	83.1	0.2904	148.75	117802.0
59	121.0	1334.0	104.534	8.170	0.000	24.10	25.13	119.80	83.7	0.2929	149.19	118750.0
60	119.1	1325.0	104.476	8.181	0.012	24.10	25.15	119.90	83.3	0.2933	148.29	118169.0

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 2.5A

DATE 12/19/79 OBSERVERS - JH VB

AVE. INNER DIA. - 2.474 INCHES; TAP SEPARATION - 15.552 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	84.5	1.60	0.288	.0096	152.11	0.32	5.64	0.0174	117890
2	109.3	2.08	0.482	.0150	148.78	0.50	7.29	0.0175	152946
3	131.0	0.57	0.685	.0064	147.50	0.30	8.74	0.0173	183774
4	152.9	1.72	0.927	.0236	146.15	0.62	10.20	0.0172	212909
5	200.1	0.72	1.581	.0086	143.41	0.14	13.36	0.0171	280002
6	175.7	0.22	1.245	.0015	143.21	0.13	11.72	0.0174	246643
7	208.6	0.55	1.587	.0105	149.13	0.16	13.92	0.0158	291264
8	184.4	0.38	1.259	.0086	149.45	0.27	12.31	0.0160	258119
9	152.9	0.17	0.899	.0023	148.62	0.22	10.21	0.0166	214902
10	132.3	0.07	0.689	.0027	148.54	0.27	8.83	0.0170	186511
11	111.0	0.02	0.498	.0017	148.44	0.28	7.41	0.0175	156964
12	83.1	0.41	0.290	.0029	148.86	0.35	5.55	0.0182	117875



## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 3A

DATE 12/21/79

OBSERVERS - VB &amp; JH

AVE. INNER DIA. - 3.0738 INCHES; TAP SEPARATION - 14.469 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	--- MANOMETER ---		WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
				HEIGHT (INCH)	STD. DEV.	TEMP. (DEG C)						
MANO. FLUID -- HG			BAROMETER -- 75.78		CM OF MERCURY	AIR TEMPERATURE -- 21.5	DEGREES CELCIUS					
1	173.2	4070.0	56.427	7.171	0.021	22.50	22.88	116.00	497.9	3.2646	130.93	542758.0
2	188.2	4099.0	56.517	7.197	0.025	22.60	22.93	116.00	498.9	3.2766	130.93	544416.0
3	175.6	4090.0	56.414	7.229	0.031	22.70	22.96	116.00	500.3	3.2912	130.97	546258.0
4	179.1	4075.0	56.260	7.185	0.022	22.70	23.00	116.00	499.3	3.2710	131.15	545625.0
5	180.0	4079.0	56.178	7.214	0.028	22.80	23.03	116.00	500.4	3.2844	131.15	547202.0
MANO. FLUID -- WATER			BAROMETER -- 75.78		CM OF MERCURY	AIR TEMPERATURE -- 21.5	DEGREES CELCIUS					
6	179.7	4114.0	94.860	34.295	0.098	24.00	23.48	122.00	299.1	1.2295	133.32	330109.0
7	160.2	4060.0	93.561	34.505	0.108	24.00	23.50	121.50	300.6	1.2371	133.54	331897.0
8	184.5	4087.0	93.186	35.057	0.066	24.10	23.52	120.80	302.0	1.2569	133.02	333603.0
9	185.7	4062.0	93.390	34.380	0.062	24.25	23.54	122.20	299.3	1.2325	133.25	330778.0
10	178.4	4070.0	93.418	34.816	0.100	24.10	23.56	122.20	300.4	1.2482	132.82	332123.0
MANO. FLUID -- WATER			BAROMETER -- 75.78		CM OF MERCURY	AIR TEMPERATURE -- 21.5	DEGREES CELCIUS					
11	178.8	4060.0	102.443	29.484	0.045	22.80	22.83	120.00	273.2	1.0575	132.10	297447.0
12	177.4	4061.0	102.550	29.468	0.059	22.80	22.86	120.00	273.0	1.0569	132.09	297509.0
13	179.0	4060.0	102.454	29.462	0.076	22.80	22.89	120.00	273.1	1.0567	132.14	297777.0
14	177.8	4118.0	102.505	30.122	0.340	22.80	22.93	120.00	277.1	1.0803	132.49	302425.0
15	178.4	4221.0	102.448	31.872	0.087	22.80	22.95	119.30	284.5	1.1431	131.92	310588.0
MANO. FLUID -- WATER			BAROMETER -- 75.76		CM OF MERCURY	AIR TEMPERATURE -- 21.95	DEGREES CELCIUS					
16	177.7	4086.0	117.408	22.439	0.070	22.85	23.05	120.00	240.0	0.8047	134.54	262563.0
17	179.3	4077.0	117.188	22.477	0.078	22.95	23.07	120.00	239.8	0.8061	134.30	262453.0
18	179.8	4080.0	117.248	22.431	0.061	23.00	23.11	120.00	239.8	0.8044	134.47	262709.0
19	179.9	4087.0	117.203	22.502	0.061	23.10	23.15	121.00	240.4	0.8069	134.54	263496.0
20	179.2	4077.0	117.157	22.567	0.107	23.05	23.16	120.80	239.9	0.8093	134.06	263028.0
MANO. FLUID -- WATER			BAROMETER -- 75.74		CM OF MERCURY	AIR TEMPERATURE -- 22.34	DEGREES CELCIUS					
21	179.0	3157.0	106.219	16.227	0.250	23.15	23.41	121.10	202.2	0.5819	135.03	222821.0
22	178.7	3151.0	106.260	16.222	0.123	23.15	23.44	120.90	201.7	0.5817	134.74	222449.0
23	179.3	3164.0	106.310	16.141	0.086	23.40	23.46	120.80	202.4	0.5788	135.61	223365.0
24	177.1	3167.0	106.427	16.156	0.159	23.45	23.50	120.70	202.6	0.5793	135.63	223696.0
25	177.6	3161.0	106.310	16.282	0.060	23.50	23.51	120.80	202.4	0.5838	134.92	223502.0
MANO. FLUID -- WATER			BAROMETER -- 75.75		CM OF MERCURY	AIR TEMPERATURE -- 22.52	DEGREES CELCIUS					
26	162.9	3166.0	135.348	10.009	0.042	23.40	23.59	118.60	160.0	0.3590	138.76	177007.0
27	128.6	3144.0	135.283	10.176	0.039	23.40	23.63	118.60	160.7	0.3649	138.16	177966.0
28	166.7	3189.0	135.426	10.295	0.071	23.45	23.66	118.80	160.9	0.3692	137.46	178297.0
29	177.0	3175.0	135.308	10.114	0.081	23.60	23.68	118.30	159.8	0.3627	137.79	177092.0
30	173.8	3166.0	135.203	10.175	0.071	23.60	23.69	119.10	159.6	0.3649	137.18	176924.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION — 3A

DATE 12/21/79

OBSERVERS - VB &amp; JH

AVE. INNER DIA. - 3.0738 INCHES; TAP SEPARATION - 14.469 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	--- MANDMETER --- HEIGHT (INCH)	--- WATER STD. TEMP. (DEG C)	--- WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
HAND. FLUID -- WATER				BAROMETER -- 75.8		CM OF MERCURY		AIR TEMPERATURE -- 22.47		DEGREES CELCIUS		
31	178.5	2200.0	120.363	5.696	0.105	23.60	23.74	118.20	121.1	0.2039	142.59	134406.0
32	161.1	2181.0	120.298	5.729	0.089	23.60	23.79	118.40	121.1	0.2055	141.97	134512.0
33	165.1	2186.0	120.283	5.893	0.072	23.70	23.79	118.30	121.2	0.2113	139.92	134596.0
34	175.4	2196.0	120.312	5.884	0.089	23.65	23.81	118.20	121.1	0.2110	139.98	134600.0
35	109.5	2134.0	120.485	5.939	0.105	23.60	23.84	118.20	121.2	0.2130	139.34	134750.0
HAND. FLUID -- WATER				BAROMETER -- 75.83		CM OF MERCURY		AIR TEMPERATURE -- 22.39		DEGREES CELCIUS		
36	169.5	2155.0	144.357	3.798	0.074	23.70	23.88	120.20	99.2	0.1362	145.25	110392.0
37	153.3	2142.0	144.521	3.905	0.054	23.75	23.92	120.10	99.2	0.1400	143.15	110537.0
38	146.2	2132.0	144.369	3.943	0.071	23.80	23.94	120.00	99.2	0.1414	142.35	110539.0
39	169.7	2156.0	144.398	3.883	0.065	23.65	23.95	119.80	99.2	0.1393	143.53	110567.0
40	146.8	2134.0	144.453	4.003	0.079	23.55	23.95	119.80	99.2	0.1435	141.21	110575.0
HAND. FLUID -- WATER				BAROMETER -- 76.32		CM OF MERCURY		AIR TEMPERATURE -- 21.18		DEGREES CELCIUS		
41	157.3	2131.0	117.307	5.775	0.034	22.85	24.73	118.50	121.4	0.2071	141.67	137448.0
42	149.3	2157.0	117.030	5.997	0.055	22.80	24.78	118.40	123.7	0.2151	141.54	140292.0
43	146.2	2116.0	118.171	5.635	0.035	22.80	24.79	118.80	120.2	0.2021	142.24	136343.0
44	149.6	2147.0	117.920	5.811	0.026	22.80	24.79	118.80	122.2	0.2084	142.16	138547.0
45	145.7	2164.0	117.540	5.999	0.060	22.75	24.81	118.90	123.9	0.2152	141.65	140508.0
HAND. FLUID -- WATER				BAROMETER -- 76.34		CM OF MERCURY		AIR TEMPERATURE -- 21.33		DEGREES CELCIUS		
46	164.3	3156.0	137.161	10.067	0.028	22.80	24.86	120.00	157.3	0.3611	136.02	176663.0
47	144.8	3140.0	137.275	10.052	0.028	22.75	24.89	121.20	157.4	0.3605	136.18	178334.0
48	158.2	3176.0	137.490	10.132	0.042	22.80	24.93	119.30	158.3	0.3634	136.41	180064.0
49	147.2	3173.0	137.365	10.208	0.034	22.75	24.94	119.30	158.9	0.3661	136.33	180729.0
50	146.6	3160.0	137.221	10.183	0.023	22.80	24.96	119.30	158.4	0.3652	136.10	180252.0
HAND. FLUID -- WATER				BAROMETER -- 76.44		CM OF MERCURY		AIR TEMPERATURE -- 21.85		DEGREES CELCIUS		
51	149.0	3142.0	112.445	15.892	0.049	22.70	24.92	118.20	192.0	0.5697	129.73	218299.0
52	134.3	3143.0	112.077	16.169	0.051	22.75	24.94	118.00	193.6	0.5800	129.53	220256.0
53	146.7	3157.0	111.819	16.346	0.258	22.80	24.96	118.40	194.2	0.5863	129.19	220972.0
54	146.8	3146.0	112.239	16.113	0.033	22.85	24.99	118.00	192.8	0.5779	129.23	219469.0
55	145.5	3165.0	112.444	16.309	0.052	22.90	25.01	117.90	193.7	0.5850	129.02	220643.0
HAND. FLUID -- WATER				BAROMETER -- 76.45		CM OF MERCURY		AIR TEMPERATURE -- 22		DEGREES CELCIUS		
56	160.0	4150.0	128.030	22.403	0.125	23.00	25.09	118.20	224.8	0.8035	126.13	256489.0
57	139.1	4166.0	128.579	22.710	0.175	23.10	25.15	119.60	225.9	0.8145	125.83	253074.0
58	144.7	4119.0	128.372	22.180	0.046	23.15	25.19	119.50	223.3	0.7954	125.98	255324.0
59	155.4	4185.0	128.434	22.808	0.067	25.20	25.20	119.40	226.3	0.8176	125.80	253904.0
60	145.0	4126.0	128.644	22.159	0.038	23.20	25.21	119.60	223.2	0.7946	126.00	255318.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 3A

DATE 12/21/79

OBSERVERS - VB &amp; JH

AVE. INNER DIA. - 3.0738 INCHES; TAP SEPARATION - 14.469 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	--- MANOMETER --- HEIGHT (INCH)	STD. DEV. (INCH)	WATER TEMP. (DEG C)	TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER
MANO. FLUID -- WATER      BAROMETER -- 76.42 CM OF MERCURY      AIR TEMPERATURE -- 22.2 DEGREES CELCIUS												
61	148.5	4150.0	121.635	25.426	0.122	23.15	25.28	117.20	237.3	0.9119	124.34	271811.0
62	143.1	4139.0	121.442	25.456	0.043	23.25	25.31	115.70	237.4	0.9130	124.28	272030.0
63	148.4	4156.0	121.444	25.643	0.058	23.25	25.33	115.40	238.1	0.9198	124.15	272934.0
64	159.8	4129.0	121.418	25.196	0.048	23.40	25.34	118.50	235.8	0.9036	124.17	270432.0
65	150.1	4149.0	121.695	25.519	0.111	23.40	25.36	119.80	237.1	0.9151	123.97	271947.0

MANO. FLUID -- WATER      BAROMETER -- 76.37 CM OF MERCURY      AIR TEMPERATURE -- 22.5 DEGREES CELCIUS												
66	147.6	4155.0	112.621	30.124	0.096	23.40	25.39	119.90	256.7	1.0803	122.73	294664.0
67	149.2	4154.0	112.960	29.933	0.086	23.50	25.42	120.20	255.8	1.0734	122.70	293770.0
68	147.0	4170.0	112.475	30.543	0.063	23.60	25.46	119.40	258.0	1.0953	122.45	296621.0
69	147.3	4139.0	112.636	30.008	0.046	23.60	25.51	121.00	255.7	1.0760	122.50	294194.0
70	145.8	4151.0	112.666	30.199	0.045	23.70	25.52	119.70	256.5	1.0829	122.45	295170.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 3A

DATE 12/21/79      OBSERVERS - VB &amp; JH

AVE. INNER DIA. - 3.0738 INCHES; TAP SEPARATION - 14.469 FEET

GROUP NO.	FLOWRATE MEAN (GPM)	STD. DEV. (GPM)	DIFF. PRESS. MEAN (PSI)	STD. DEV. (PSI)	HAZEN-WILLIAMS MEAN	STD. DEV.	VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
1	499.4	1.03	3.278	.0106	131.03	0.12	21.59	0.0182	545252
2	300.3	1.16	1.241	.0114	133.19	0.28	12.98	0.0190	331702
3	276.2	4.97	1.079	.0373	132.15	0.21	11.94	0.0195	301149
4	240.0	0.23	0.806	.0020	134.38	0.21	10.38	0.0194	262850
5	202.3	0.34	0.581	.0021	135.19	0.41	8.74	0.0196	223167
6	160.2	0.59	0.364	.0037	137.87	0.62	6.93	0.0196	177457
7	121.1	0.04	0.209	.0040	140.76	1.43	5.24	0.0197	134573
8	99.2	0.02	0.140	.0027	143.10	1.50	4.29	0.0197	110522
9	122.3	1.55	0.210	.0056	141.85	0.32	5.29	0.0194	138627
10	158.1	0.68	0.363	.0025	136.21	0.16	6.83	0.0201	179709
11	193.3	0.87	0.580	.0066	129.35	0.29	8.36	0.0215	219928
12	224.7	1.43	0.805	.0106	125.95	0.14	9.72	0.0220	256802
13	237.1	0.81	0.913	.0059	124.18	0.14	10.25	0.0224	271831
14	256.5	0.95	1.082	.0085	122.57	0.14	11.09	0.0227	294884

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 3B  
 DATE DEC 19 & 2 OBSERVERS - JH VB MH  
 AVE. INNER DIA. - 3.0994 INCHES; TAP SEPARATION - 13.635 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	--- MANOMETER --- HEIGHT (INCH)	STD. DEV. (DEG C)	WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER	
MANO. FLUID -- WATER				BAROMETER -- 75.74		CM OF MERCURY	AIR TEMPERATURE -- 21.84		DEGREES CELCIUS			
1	141.7	2122.0	144.890	2.681	0.076	22.90	23.78	118.70	98.6	0.0961	165.07	108565.0
2	173.1	2203.0	144.672	2.791	0.070	23.00	23.81	118.60	101.2	0.1001	165.82	111522.0
3	166.3	2193.0	144.539	2.835	0.096	23.00	23.85	118.30	101.1	0.1017	164.32	111543.0
4	151.8	2148.0	144.550	2.720	0.093	23.20	23.87	118.40	99.6	0.0976	165.49	109901.0
5	146.6	2115.0	144.721	2.701	0.086	23.30	23.90	118.40	98.1	0.0969	163.63	108310.0
MANO. FLUID -- WATER				BAROMETER -- 75.7		CM OF MERCURY	AIR TEMPERATURE -- 21.96		DEGREES CELCIUS			
6	160.1	2095.0	120.574	3.738	0.040	23.30	23.92	120.00	115.7	0.1341	161.95	127842.0
7	166.4	2117.0	120.767	3.774	0.061	23.35	23.96	119.90	116.5	0.1353	162.18	128781.0
8	159.4	2098.0	120.712	3.796	0.051	23.40	23.98	119.90	115.8	0.1361	160.74	128100.0
9	154.4	2142.0	120.693	3.922	0.050	23.40	24.00	120.00	118.8	0.1407	161.95	131424.0
10	159.2	2135.0	120.044	3.965	0.123	23.40	23.99	119.80	118.7	0.1422	160.91	131312.0
MANO. FLUID -- WATER				BAROMETER -- 75.68		CM OF MERCURY	AIR TEMPERATURE -- 21.96		DEGREES CELCIUS			
11	151.5	3187.0	135.514	7.417	0.037	23.05	24.13	118.40	161.5	0.2660	156.09	179232.0
12	142.2	3205.0	135.686	7.446	0.045	23.00	24.15	118.30	162.8	0.2671	156.96	180690.0
13	140.8	3185.0	135.629	7.418	0.041	23.00	24.17	118.10	161.9	0.2661	156.39	179743.0
14	152.0	3164.0	135.735	7.227	0.048	23.00	24.18	118.20	160.0	0.2592	156.81	177739.0
15	142.6	3156.0	135.757	7.280	0.087	23.10	24.20	118.20	160.1	0.2611	156.24	177867.0
MANO. FLUID -- WATER				BAROMETER -- 75.66		CM OF MERCURY	AIR TEMPERATURE -- 22.02		DEGREES CELCIUS			
16	142.6	3203.0	106.552	12.108	0.050	23.05	24.26	120.00	207.2	0.4342	153.57	230441.0
17	139.7	3196.0	106.579	12.097	0.103	23.10	24.27	119.90	206.8	0.4306	154.03	230122.0
18	136.6	3169.0	106.673	11.834	0.039	23.10	24.28	120.30	205.0	0.4244	153.89	228168.0
19	139.9	3174.0	106.643	11.908	0.095	23.15	24.30	120.50	205.2	0.4270	153.50	228455.0
20	140.6	3199.0	106.734	11.992	0.071	23.20	24.31	120.00	206.7	0.4300	154.02	230136.0
MANO. FLUID -- WATER				BAROMETER -- 75.46		CM OF MERCURY	AIR TEMPERATURE -- 19.56		DEGREES CELCIUS			
21	141.9	4151.0	124.633	15.145	0.079	21.25	23.85	121.60	232.0	0.5433	152.36	255883.0
22	144.0	4147.0	125.274	14.918	0.063	21.25	23.89	121.40	230.4	0.5352	152.59	254404.0
23	143.6	4140.0	124.061	15.233	0.113	21.00	23.94	121.60	232.3	0.5465	152.09	256736.0
24	148.0	4147.0	124.684	15.101	0.091	21.05	24.00	121.50	231.3	0.5418	152.15	255939.0
25	128.5	4135.0	125.885	14.892	0.081	21.05	24.04	121.50	229.5	0.5343	152.12	254184.0
MANO. FLUID -- WATER				BAROMETER -- 75.47		CM OF MERCURY	AIR TEMPERATURE -- 19.89		DEGREES CELCIUS			
26	140.9	4166.0	102.331	22.683	0.095	21.05	24.06	121.50	283.7	0.8138	149.76	314273.0
27	145.2	4152.0	102.554	22.406	0.043	21.15	24.08	120.60	281.8	0.8039	149.74	312294.0
28	157.8	4150.0	103.199	21.999	0.049	21.20	24.08	120.90	279.0	0.7892	149.75	309212.0
29	142.7	4154.0	101.978	22.808	0.155	21.25	24.10	120.80	283.7	0.8183	149.32	314542.0
30	146.3	4142.0	102.396	22.354	0.052	21.25	24.11	120.70	281.4	0.8020	149.75	312105.0

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 3B

DATE DEC 19 &amp; 2

OBSERVERS - JH VB MH

AVE. INNER DIA. - 3.0994 INCHES; TAP SEPARATION - 13.635 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	--- MANOMETER ---		WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER
				HEIGHT (INCH)	STD. DEV. (INCH)	TEMP. (DEG C)					
MANO. FLUID -- WATER				BAROMETER -- 74.73 CM OF MERCURY		AIR TEMPERATURE -- 21.62 DEGREES CELCIUS					
31	150.8	4151.0	101.074	22.131	0.019	22.80	23.66	120.30	285.4	0.7937	152.71 313577.0
32	147.0	4152.0	101.049	22.132	0.034	22.85	23.74	120.40	285.8	0.7937	152.94 314557.0
33	148.2	4158.0	101.139	22.154	0.020	23.00	23.75	120.30	285.9	0.7945	152.90 314720.0
34	142.3	4153.0	101.216	22.116	0.047	23.00	23.78	120.40	285.7	0.7931	152.96 314748.0
35	148.5	4150.0	101.038	22.105	0.041	23.00	23.80	120.40	285.6	0.7928	152.92 314711.0
MANO. FLUID -- WATER				BAROMETER -- 74.75 CM OF MERCURY		AIR TEMPERATURE -- 22.1 DEGREES CELCIUS					
36	148.0	4149.0	123.298	15.033	0.036	23.40	23.87	120.10	234.0	0.5391	154.34 258238.0
37	148.6	4143.0	123.204	15.056	0.035	23.40	23.89	120.10	233.8	0.5399	154.08 258117.0
38	148.3	4147.0	123.289	15.090	0.058	23.55	23.91	120.20	233.9	0.5411	153.95 258324.0
39	148.8	4144.0	123.091	15.107	0.037	23.55	23.95	120.20	234.1	0.5417	153.98 258729.0
40	147.3	4138.0	123.078	15.058	0.043	23.60	23.98	120.10	233.8	0.5400	154.09 258527.0
MANO. FLUID -- WATER				BAROMETER -- 74.75 CM OF MERCURY		AIR TEMPERATURE -- 22.35 DEGREES CELCIUS					
41	146.5	3147.0	103.946	12.069	0.068	23.60	24.01	120.80	208.2	0.4328	154.61 230399.0
42	143.4	3145.0	103.496	12.166	0.066	23.75	24.04	120.10	209.2	0.4362	154.68 231620.0
43	148.2	3144.0	103.980	11.996	0.035	23.80	24.05	121.10	207.8	0.4301	154.83 230145.0
44	147.5	3143.0	103.395	12.169	0.036	23.85	24.08	121.30	208.9	0.4363	154.51 231568.0
45	147.5	3149.0	103.551	12.144	0.034	23.95	24.10	121.10	209.0	0.4354	154.75 231779.0
MANO. FLUID -- WATER				BAROMETER -- 74.77 CM OF MERCURY		AIR TEMPERATURE -- 23 DEGREES CELCIUS					
46	146.1	3139.0	133.543	7.342	0.033	23.75	24.14	121.60	161.6	0.2632	157.06 179359.0
47	145.9	3137.0	132.666	7.458	0.092	23.90	24.18	121.90	162.6	0.2674	156.66 189586.0
48	147.0	3139.0	134.632	7.245	0.021	24.20	24.21	121.60	160.3	0.2597	156.87 178113.0
49	147.9	3139.0	134.554	7.242	0.058	24.20	24.23	121.70	160.3	0.2596	156.94 178237.0
50	144.5	3135.0	133.179	7.414	0.046	24.35	24.25	121.70	161.9	0.2658	156.54 180116.0
MANO. FLUID -- WATER				BAROMETER -- 74.82 CM OF MERCURY		AIR TEMPERATURE -- 23.18 DEGREES CELCIUS					
51	148.5	2128.0	126.261	3.668	0.032	24.25	24.40	119.50	113.1	0.1315	159.88 126149.0
52	151.6	2129.0	125.444	3.703	0.038	24.30	24.42	119.00	113.7	0.1328	159.93 126889.0
53	147.9	2127.0	125.442	3.735	0.025	24.30	24.44	119.50	113.8	0.1339	159.32 127052.0
54	146.8	2126.0	124.318	3.796	0.042	24.55	24.45	119.40	114.8	0.1361	159.37 128234.0
55	147.0	2128.0	126.098	3.682	0.031	24.55	24.47	119.40	113.3	0.1320	159.89 126591.0
MANO. FLUID -- WATER				BAROMETER -- 74.85 CM OF MERCURY		AIR TEMPERATURE -- 23.05 DEGREES CELCIUS					
56	155.0	2129.0	148.425	2.601	0.045	24.70	24.50	118.80	95.9	0.0932	163.34 107236.0
57	140.1	2126.0	153.398	2.480	0.030	24.55	24.52	119.20	93.4	0.0839	163.15 104435.0
58	148.2	2126.0	149.512	2.622	0.044	24.60	24.54	119.20	95.4	0.0940	161.77 106749.0
59	147.9	2123.0	149.054	2.612	0.016	24.65	24.56	119.20	95.6	0.0936	162.38 106975.0
60	146.2	2123.0	150.575	2.559	0.017	24.65	24.58	119.30	94.7	0.0921	162.32 106030.0

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 3B  
 DATE DEC 19 & 2 OBSERVERS - JH VR KH  
 AVE. INNER DIA. - 3.0994 INCHES; TAP SEPARATION - 13.635 FEET

GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
	MEAN (GPM)	STD. DEV.	MEAN (PSI)	STD. DEV.	MEAN	STD. DEV.			
1	99.7	1.43	0.098	.0023	164.87	0.89	4.24	0.0151	109968
2	117.1	1.52	0.138	.0035	161.54	0.67	4.98	0.0153	129492
3	161.3	1.19	0.264	.0035	156.50	0.37	6.86	0.0155	179054
4	206.2	0.99	0.429	.0037	153.80	0.25	8.77	0.0154	229464
5	231.1	1.14	0.540	.0053	152.26	0.21	9.83	0.0155	255430
6	281.9	1.94	0.805	.0113	149.66	0.19	11.99	0.0155	312485
7	285.7	0.20	0.794	.0007	152.89	0.10	12.15	0.0149	314463
8	233.9	0.11	0.540	.0011	154.09	0.16	9.95	0.0151	258407
9	208.6	0.61	0.434	.0027	154.68	0.13	8.87	0.0153	231100
10	161.4	1.03	0.263	.0035	156.81	0.21	6.86	0.0155	179282
11	113.7	0.67	0.133	.0018	159.68	0.30	4.84	0.0158	126983
12	95.0	1.01	0.092	.0021	162.59	0.65	4.04	0.0157	106285

## AISI PIPE FRICTION TESTS

PIPE DESIGNATION -- 3B

DATE DEC 19 &amp; 2

OBSERVERS - JH VB MH

AVE. INNER DIA. - 3.0994 INCHES; TAP SEPARATION - 13.635 FEET

RUN NO. (RN)	TARE WT (LB)	GROSS WT (LB)	DIVERT TIME (SEC)	--- MANOMETER ---		WATER TEMP. (DEG C)	STATIC PRESS. (PSIA)	FLOW RATE (GPM)	DIFF. PRESS. (PSI)	HAZEN WILLIAMS COEFF.	PIPE REYNOLDS NUMBER
MANO. FLUID -- WATER			BAROMETER --		74.73	CM OF MERCURY	AIR TEMPERATURE --		21.62	DEGREES CELCIUS	
31	150.8	4151.0	101.074	22.131	0.019	22.80	23.66	120.30	285.4	0.7937	152.71 313577.0
32	147.0	4152.0	101.049	22.132	0.034	22.85	23.74	120.40	285.8	0.7937	152.94 314557.0
33	148.2	4158.0	101.139	22.154	0.020	23.00	23.75	120.30	285.9	0.7945	152.90 314720.0
34	142.3	4153.0	101.216	22.116	0.047	23.00	23.78	120.40	285.7	0.7931	152.96 314748.0
35	148.5	4150.0	101.039	22.105	0.041	23.00	23.80	120.40	285.6	0.7928	152.92 314711.0
MANO. FLUID -- WATER			BAROMETER --		74.75	CM OF MERCURY	AIR TEMPERATURE --		22.1	DEGREES CELCIUS	
36	149.0	4149.0	123.298	15.033	0.036	23.40	23.87	120.10	234.0	0.5391	154.34 258239.0
37	148.6	4143.0	123.204	15.056	0.035	23.40	23.89	120.10	233.8	0.5399	154.08 258117.0
38	148.3	4147.0	123.289	15.090	0.058	23.55	23.91	120.20	233.9	0.5411	153.95 258324.0
39	148.8	4144.0	123.091	15.107	0.037	23.55	23.95	120.20	234.1	0.5417	153.98 258729.0
40	147.3	4138.0	123.078	15.058	0.043	23.60	23.98	120.10	233.8	0.5400	154.09 258527.0
MANO. FLUID -- WATER			BAROMETER --		74.75	CM OF MERCURY	AIR TEMPERATURE --		22.35	DEGREES CELCIUS	
41	146.5	3147.0	103.946	12.069	0.068	23.60	24.01	120.80	208.2	0.4328	154.61 230399.0
42	143.4	3145.0	103.496	12.166	0.066	23.75	24.04	120.10	209.2	0.4362	154.69 231620.0
43	148.2	3144.0	103.980	11.996	0.035	23.80	24.05	121.10	207.8	0.4301	154.83 230145.0
44	147.5	3143.0	103.395	12.169	0.036	23.85	24.08	121.30	208.9	0.4363	154.51 231568.0
45	147.5	3149.0	103.551	12.144	0.034	23.95	24.10	121.10	209.0	0.4354	154.75 231779.0
MANO. FLUID -- WATER			BAROMETER --		74.77	CM OF MERCURY	AIR TEMPERATURE --		23	DEGREES CELCIUS	
46	146.1	3139.0	133.543	7.342	0.033	23.75	24.14	121.60	161.6	0.2632	157.06 179359.0
47	145.9	3137.0	132.666	7.458	0.092	23.90	24.18	121.90	162.6	0.2674	156.66 189586.0
48	147.0	3139.0	134.632	7.245	0.021	24.20	24.21	121.60	160.3	0.2597	156.87 178113.0
49	147.9	3139.0	134.554	7.242	0.058	24.20	24.23	121.70	160.3	0.2596	156.94 178237.0
50	144.5	3135.0	133.179	7.414	0.046	24.35	24.25	121.70	161.9	0.2658	156.54 180116.0
MANO. FLUID -- WATER			BAROMETER --		74.82	CM OF MERCURY	AIR TEMPERATURE --		23.18	DEGREES CELCIUS	
51	148.5	2128.0	126.261	3.668	0.032	24.25	24.40	119.50	113.1	0.1315	159.88 126149.0
52	151.6	2129.0	125.444	3.703	0.038	24.30	24.42	119.00	113.7	0.1328	159.93 126899.0
53	147.9	2127.0	125.442	3.735	0.025	24.30	24.44	119.50	113.8	0.1339	159.32 127052.0
54	146.8	2126.0	124.318	3.796	0.042	24.55	24.45	119.40	114.8	0.1361	159.37 128234.0
55	147.0	2128.0	126.098	3.682	0.031	24.55	24.47	119.40	113.3	0.1320	159.89 126591.0
MANO. FLUID -- WATER			BAROMETER --		74.85	CM OF MERCURY	AIR TEMPERATURE --		23.05	DEGREES CELCIUS	
56	155.0	2129.0	148.425	2.601	0.045	24.70	24.50	118.80	95.9	0.0932	163.34 107236.0
57	140.1	2126.0	153.388	2.490	0.030	24.55	24.52	119.20	93.4	0.0839	163.15 104435.0
58	148.2	2126.0	149.512	2.622	0.044	24.60	24.54	119.20	95.4	0.0940	161.77 106749.0
59	147.9	2123.0	149.054	2.612	0.016	24.65	24.56	119.20	95.6	0.0936	162.38 106975.0
60	146.2	2123.0	150.575	2.569	0.017	24.65	24.58	119.30	94.7	0.0921	162.32 106030.0

AISI PIPE FRICTION TESTS  
 PIPE DESIGNATION -- 3B  
 DATE DEC 19 & 2 OBSERVERS - JH VB MH  
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GROUP NO.	FLOWRATE		DIFF. PRESS.		HAZEN-WILLIAMS		VELOCITY (FT/SEC)	FRICTION FACTOR	PIPE REYNOLDS NUMBER
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1	99.7	1.43	0.098	.0023	164.87	0.89	4.24	0.0151	109968
2	117.1	1.52	0.138	.0035	161.54	0.67	4.98	0.0153	129492
3	161.3	1.19	0.264	.0035	156.50	0.37	6.86	0.0155	179054
4	206.2	0.99	0.429	.0037	153.80	0.25	8.77	0.0154	229464
5	231.1	1.14	0.540	.0053	152.26	0.21	9.83	0.0155	255430
6	281.9	1.94	0.805	.0113	149.66	0.19	11.99	0.0155	312485
7	285.7	0.20	0.794	.0007	152.89	0.10	12.15	0.0149	314463
8	233.9	0.11	0.540	.0011	154.09	0.16	9.95	0.0151	258407
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10	161.4	1.03	0.263	.0035	156.81	0.21	6.86	0.0155	179282
11	113.7	0.67	0.133	.0018	159.68	0.30	4.84	0.0158	126983
12	95.0	1.01	0.092	.0021	162.59	0.65	4.04	0.0157	106285



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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.) Two sets of black steel pipes have been tested at the National Bureau of Standards (NBS) to determine their frictional loss characteristics. Twenty foot lengths of pipe furnished by the American Iron and Steel Institute ranging from one to three inches nominal pipe size were tested using water in the primary flow measurement facilities at NBS. These facilities use static gravimetric techniques with precision timing to determine flow rates to within $\pm 0.13\%$ based upon three standard deviations. Pipe pressure losses were measured using water and mercury manometers for pipe flow velocities ranging from 4 to 16 feet per second. Frictional loss characteristics of each pipe characterized using the conventional Hazen-Williams formulation at each flowrate.			
17. KEY WORDS (six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons) Friction factor; Hazen-Williams coefficient.			
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