Fluid Mechanics - Course 223

APPENDIX

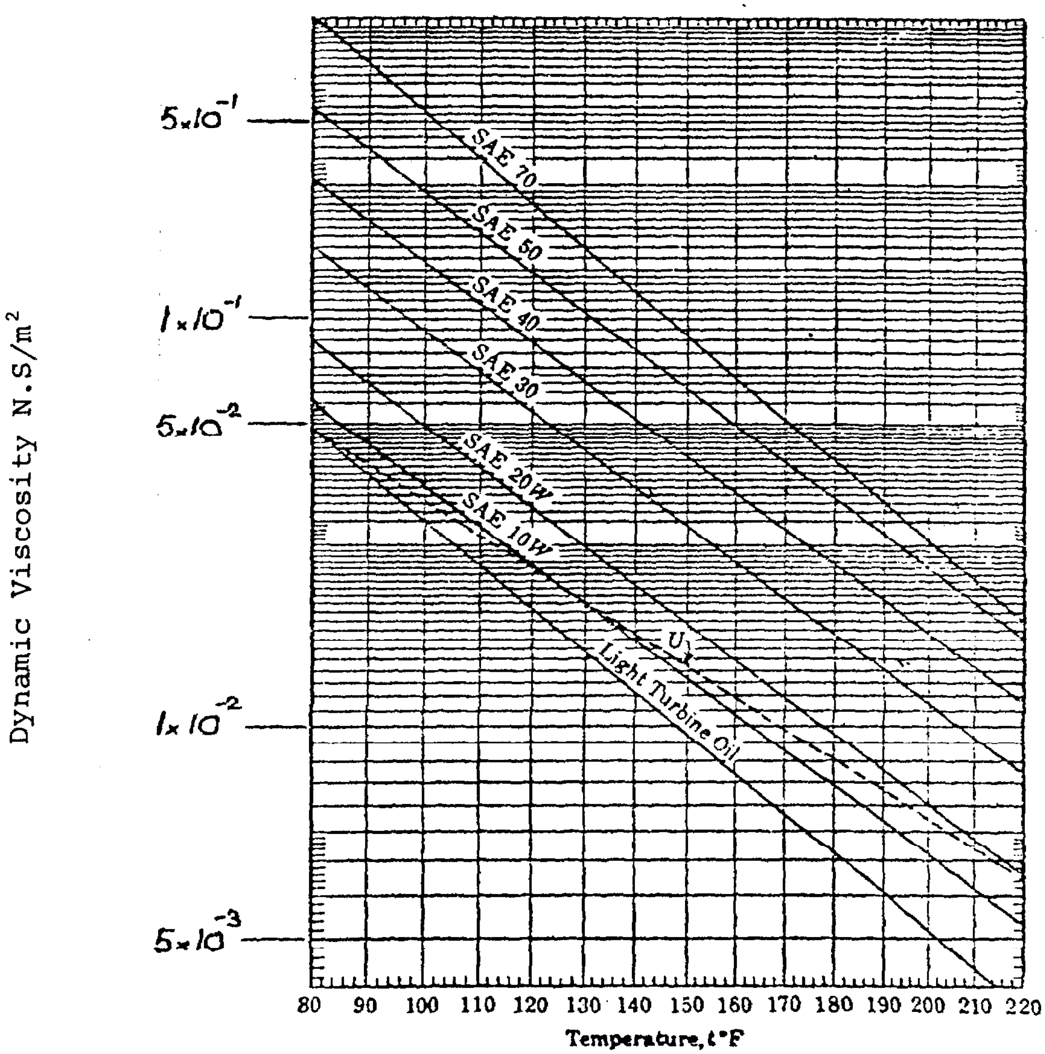
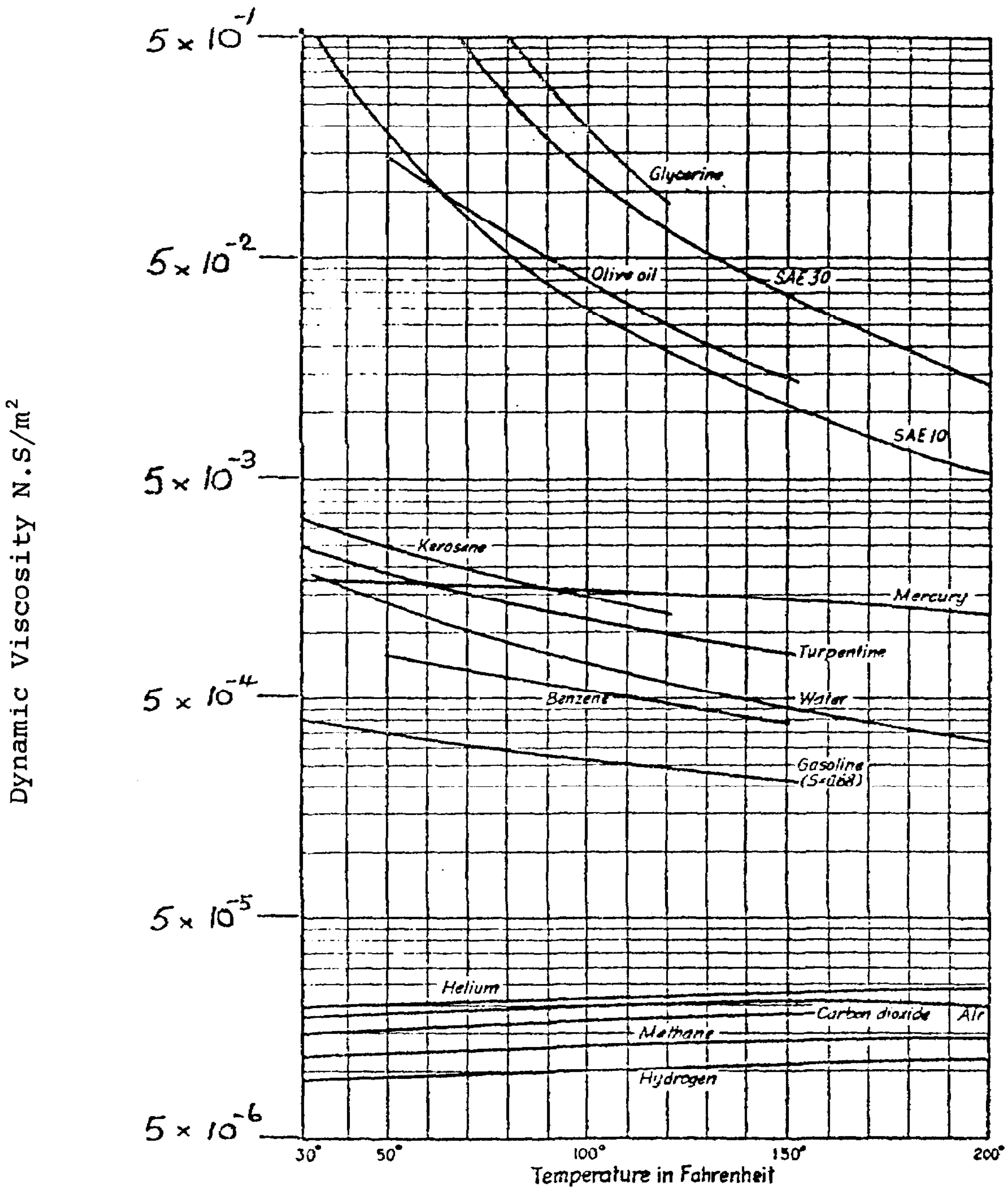


Figure 1.1



Viscosity graph.

Figure 1.2

Relative Roughness of Pipe Materials and Friction Factors For Complete Turbulence[18]

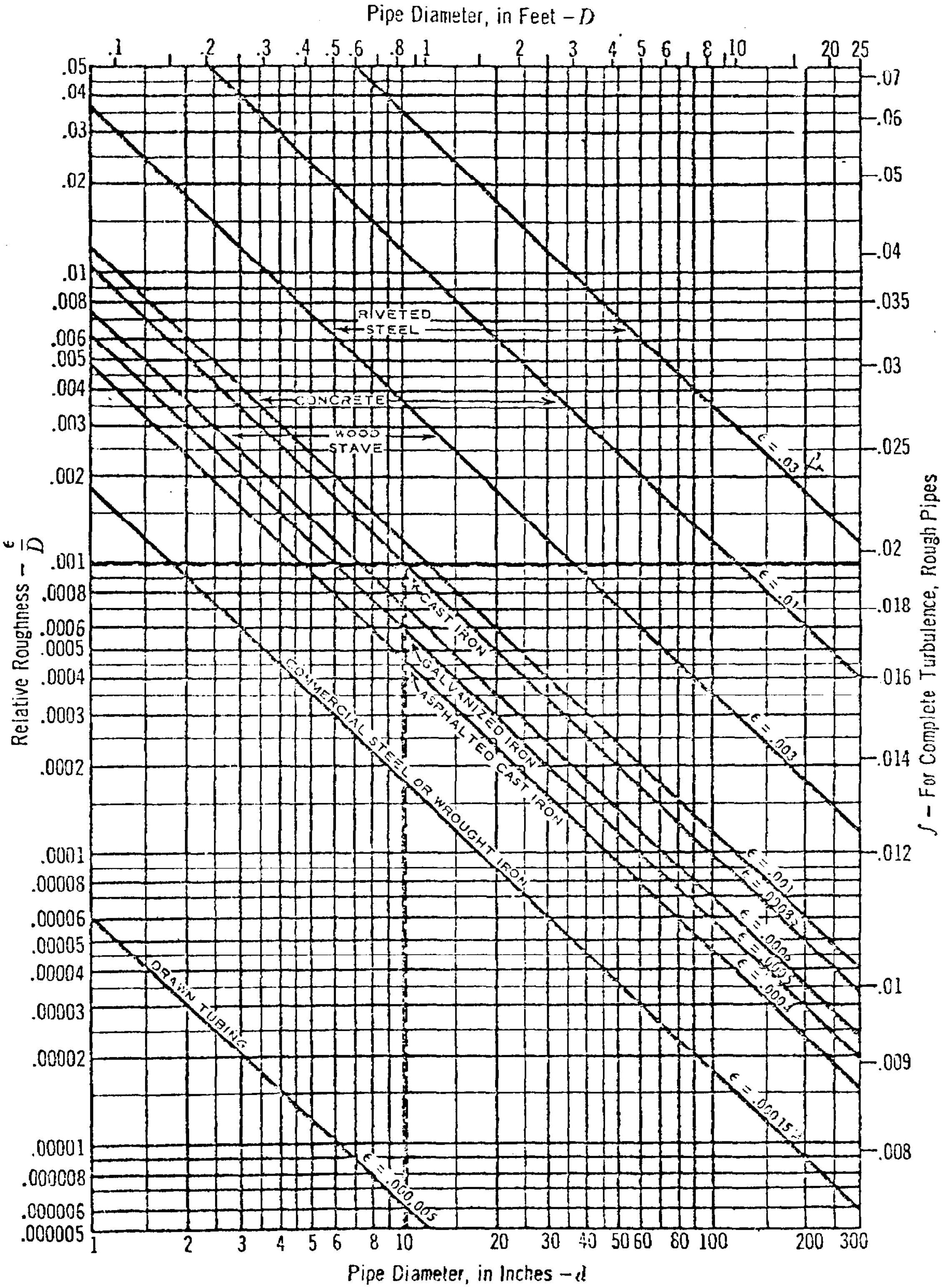


Figure 3.1

Friction Factors for Any Type of Commercial Pipe[18]

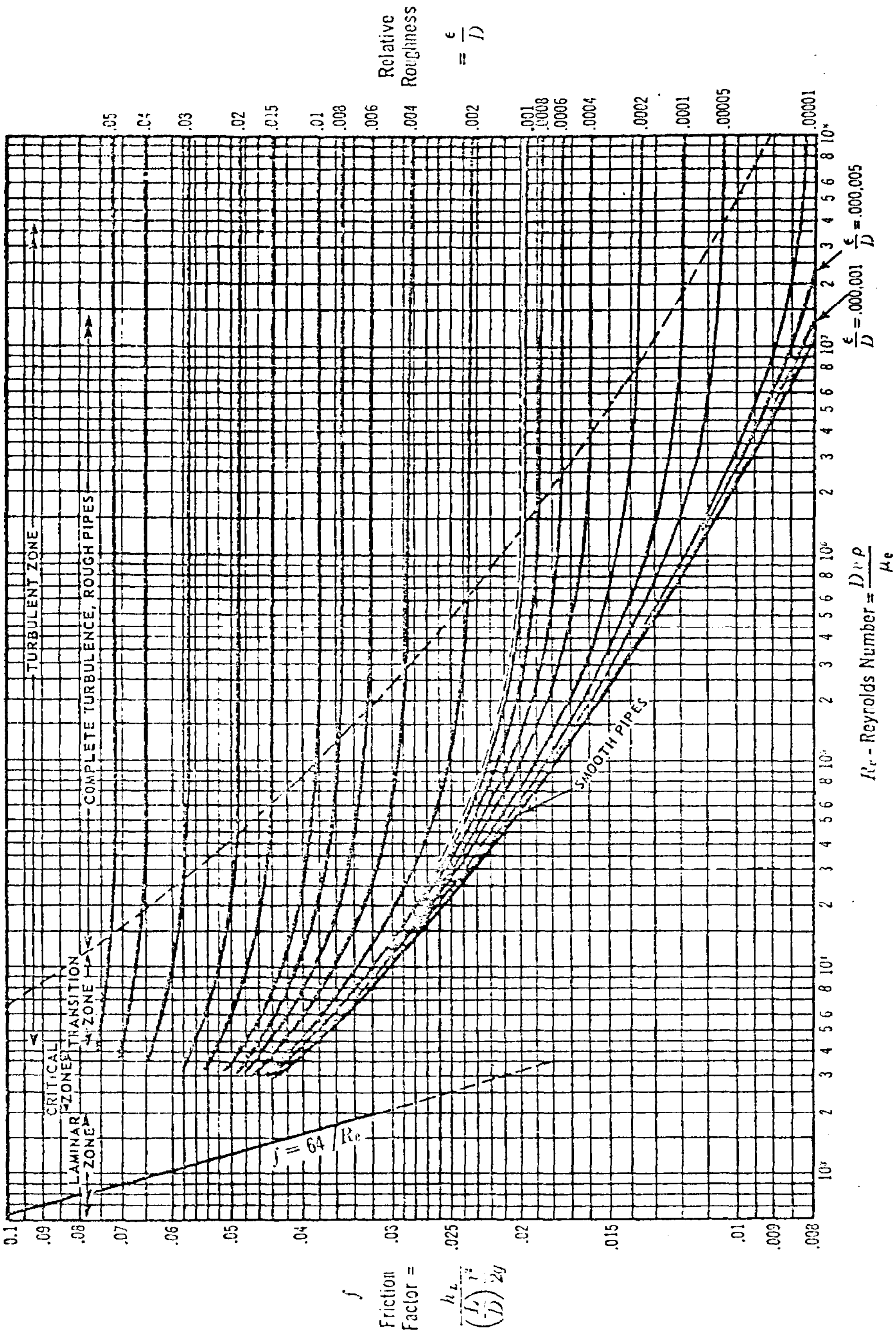


Figure 3.2

Table 3.3 Area of Schedule 40 Pipe in Square Metres

Nom. Pipe Size	O.D. (in)	Schedule 40			
		t (in)	I.D. (in)	Area (in^2)	Area x10^{-4} (m^2)
1/8	.405	.068	.269	.057	.367
1/4	.540	.088	.364	.104	.671
3/8	.675	.091	.493	.191	1.23
1/2	.840	.109	.622	.304	1.96
3/4	1.050	.113	.824	.533	3.44
1	1.315	.133	1.049	.864	5.57
1 1/4	1.660	.140	1.380	1.496	9.65
1 1/2	1.900	.145	1.610	2.036	13.13
2	2.375	.154	2.067	3.356	21.65
2 1/2	2.875	.203	2.469	4.788	30.89
3	3.500	.216	3.068	7.393	47.69
3 1/2	4.000	.226	3.548	9.887	63.79
4	4.500	.237	4.026	12.730	82.13
5	5.563	.258	5.047	20.006	129.1
6	6.625	.280	6.065	28.890	186.4
8	8.625	.322	7.981	50.027	322.8
10	10.750	.365	10.020	78.854	508.7
12	12.750	.406	11.938	111.93	722.1
14	14.000	.438	13.124	135.28	872.8
16	16.000	.500	15.000	176.72	1140
18	18.000	.562	16.876	223.68	1443
20	20.000	.593	18.814	278.00	1794
24	24.000	.687	22.626	402.07	2594

Example: Area of an 8 in dia Schedule 40 pipe is 322.8x10^{-4}m^2

Table 3.4 **Area of Schedule 80 Pipe in Square Metres**

Nom. Pipe Size	O.D. (in)	Schedule 80			
		t (in)	I.D. (in)	Area (in²)	Area x10⁻⁴ (m²)
1/8	.405	.095	.215	.036	.234
1/4	.540	.119	.302	.072	.462
3/8	.675	.126	.423	.141	.907
1/2	.840	.147	.546	.234	1.510
3/4	1.050	.154	.742	.432	2.790
1	1.315	.179	.957	.719	4.64
1 1/4	1.660	.191	1.278	1.283	8.276
1 1/2	1.900	.200	1.500	1.767	11.40
2	2.375	.218	1.939	2.953	19.05
2 1/2	2.875	.276	2.323	4.238	27.34
3	3.500	.300	2.900	6.605	42.61
3 1/2	4.000	.318	3.364	8.888	57.34
4	4.500	.337	3.826	11.497	74.17
5	5.563	.375	4.813	18.194	117.4
6	6.625	.432	5.761	26.067	168.2
8	8.625	.500	7.625	45.663	294.6
10	10.750	.593	9.564	71.840	463.5
12	12.750	.687	11.376	101.64	655.8
14	14.000	.750	12.500	122.72	791.7
16	16.000	.843	14.314	160.92	1038
18	18.000	.957	16.126	204.24	1318
20	20.000	1.031	17.938	252.72	1630
24	24.000	1.218	21.564	365.22	2356

Table 3.5 Area of Schedule 160 Pipe in Square Metres

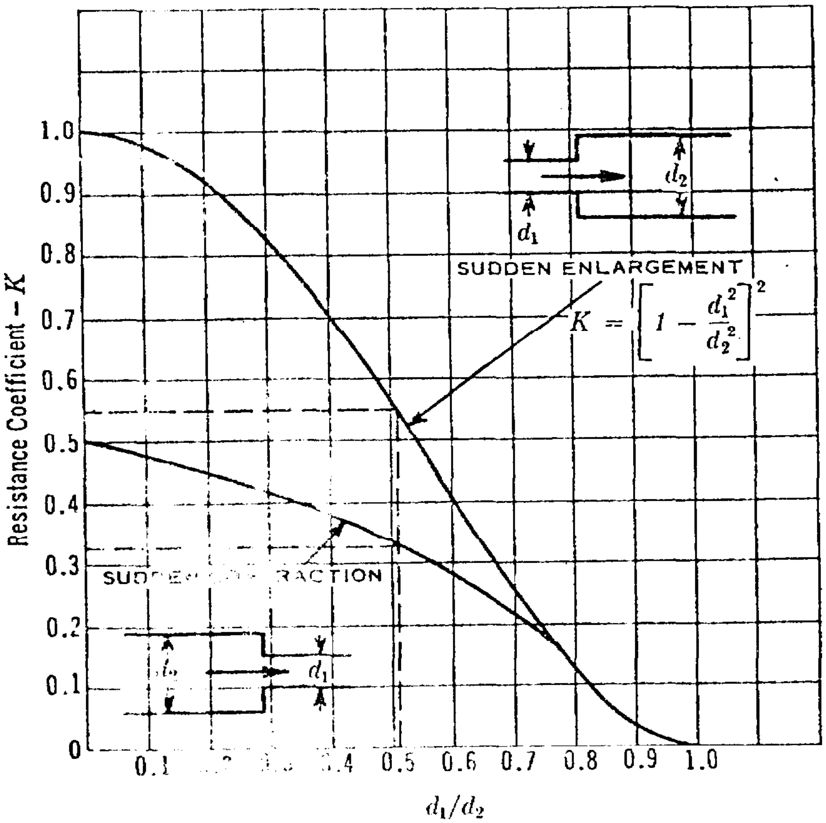
Nom. Pipe Size	O.D. (in)	Schedule 160			
		t (in)	I.D. (in)	Area (in²)	Area x10⁻⁴ (m²)
1/8	.405	-----	-----	-----	------
1/4	.540	-----	-----	-----	------
3/8	.675	-----	-----	-----	------
1/2	.840	.187	.466	.171	1.100
3/4	1.050	.218	.614	.296	1.910
1	1.315	.250	.815	.522	3.366
1 1/4	1.660	.250	1.160	1.057	6.818
1 1/2	1.900	.281	1.338	1.406	9.071
2	2.375	.343	1.689	2.241	14.46
2 1/2	2.875	.375	2.125	3.547	22.88
3	3.500	.438	2.624	5.408	34.89
3 1/2	4.000	-----	-----	-----	-----
4	4.500	.531	3.438	9.283	59.98
5	5.563	.625	4.313	14.610	94.26
6	6.625	.718	5.189	21.15	136.4
8	8.625	.906	6.813	36.45	235.2
10	10.750	1.125	8.500	56.75	366.1
12	12.750	1.312	10.126	80.53	519.6
14	14.000	1.406	11.188	98.31	634.2
16	16.000	1.593	12.814	128.96	832.0
18	18.000	1.781	14.438	163.72	1056
20	20.000	1.968	16.064	202.67	1308
24	24.000	2.343	19.314	292.98	1890

LOSS COEFFICIENTS FOR COMMERCIAL PIPE FITTINGS

Fitting	K
Globe valve, fully open	10
Angle valve, fully open	5
Swing check valve, fully open	2.5
Closed return bend	2.2
Tee, through side outlet	1.8
Short radius elbow	0.9
Medium radius elbow	0.8
Long radius elbow	0.6
45-degree elbow	0.4
Gate valve, fully open	0.2
Gate valve, 3/4 open	1
Gate valve, 1/2 open	5.6
Gate valve, 1/4 open	24

Figure 4.1

Resistance Due to Sudden Enlargements and Contractions[20]



Sudden enlargement: The resistance coefficient K for a sudden enlargement from 6-inch Schedule 40 pipe to 12-inch Schedule 40 pipe is 0.55, based on the 6-inch pipe size.

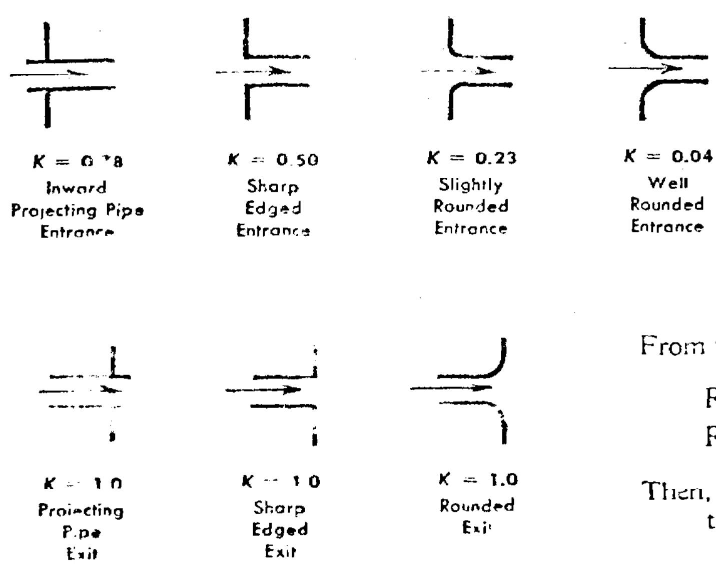
$$\frac{d_1}{d_2} = \frac{6.065}{11.938} = 0.51$$

Sudden contraction: The resistance coefficient K for a sudden contraction from 12-inch Schedule 40 pipe to 6-inch Schedule 40 pipe is 0.33, based on the 6-inch pipe size.

$$\frac{d_1}{d_2} = \frac{6.065}{11.938} = 0.51$$

Note: The values for the resistance coefficient, K, are based on velocity in the small pipe. To determine K values in terms of the greater diameter, multiply the chart values by $(d_2/d_1)^4$.

Resistance Due to Pipe Entrance and Exit



Problem: Determine the total resistance coefficient for a pipe one diameter long having a sharp edged entrance and a sharp edged exit.

Solution: The resistance of pipe one diameter long is small and can be neglected ($K = f\,L/D$).

From the diagrams, note:

Resistance for a sharp edged entrance = 0.5
Resistance for a sharp edged exit = 1.0

Then,
the total resistance, K, for the pipe = 1.5

Figure 4.2

Schedule (Thickness) of Steel Pipe Used in Obtaining Resistance Of Valves and Fittings of Various Pressure Classes by Test*

Valve or Fitting ASA Pressure Classification (Steam Rating)		Schedule No. of Pipe (Thickness)
250-Pound and Lower		Schedule 40
300-Pound to 600-Pound		Schedule 80
900-Pound		Schedule 120
1500-Pound		Schedule 160
2500-Pound	Sizes ½ to 6-inch	xx (Double Extra Strong)
	Sizes 8-inch and larger	Schedule 160

*These schedule numbers have been arbitrarily selected only for the purpose of identifying the various pressure classes of valves and fittings with specific pipe dimensions for the interpretation of flow test data; they should not be construed as a recommendation for installation purposes.

Representative Equivalent Length‡ in Pipe Diameters (L/D) Of Various Valves and Fittings

Description of Product				Equivalent Length In Pipe Diameters (L/D)
Valves	Conventional Globe	With no obstruction in flat, bevel, or plug type seat	Fully open	340
		With wing or pin guided disc	Fully open	450
	Y-Pattern Globe	With stem 60 degrees from run of pipe line	Fully open	175
		With stem 45 degrees from run of pipe line	Fully open	145
	Conventional Angle	With no obstruction in flat, bevel, or plug type seat	Fully open	145
		With wing or pin guided disc	Fully open	200
	Conventional Wedge Disc, Double Disc, or Plug Gate		Fully open	13
			Three-quarters open	35
			One-half open	160
			One-quarter open	900
	Pulp Stock Gate		Fully open	17
			Three-quarters open	50
			One-half open	260
			One-quarter open	1200
	Conduit Pipe Line Gate		Fully open	3**
	Butterfly (6-inch and larger)		Fully open	20
	Conventional Swing Check		0.5† . . . Fully open	135
	Clearway Swing Check		0.5† . . . Fully open	50
	Globe Lift Check or Stop-Check		2.0† . . . Fully open	Same as Conv. Globe
	Angle Lift Check or Stop-Check		2.0† . . . Fully open	Same as Conv. Angle
	Foot Valves	With strainer and poppet lift-type disc	0.3† . . . Fully open	420
		With strainer and leather-hinged disc	0.4† . . . Fully open	75
	In-Line Ball Check	2.5 vertical and 0.25 horizontal†	Fully open	150
Straight-Through Cocks		Rectangular plug port area equal to 100% of pipe area	Fully open	18
Three-Way Cocks		Rectangular plug port area equal to 80% of pipe area (fully open)	Flow straight through	44
			Flow through branch	140
Fittings	90 Degree Standard Elbow			30
	45 Degree Standard Elbow			16
	90 Degree Long Radius Elbow			20
	90 Degree Street Elbow			50
	45 Degree Street Elbow			26
	Square Corner Elbow			57
	Standard Tee	With flow through run		20
		With flow through branch		60
	Close Pattern Return Bend			50
Pipe	90 Degree Pipe Bends			See Page A-27
	Miter Bends			See Page A-27
	Sudden Enlargements and Contractions			See Page A-26
	Entrance and Exit Losses			See Page A-26

**Exact equivalent length is equal to the length between flange faces or welding ends.

†Minimum calculated pressure drop (psi) across valve to provide sufficient flow to lift disc fully.

‡For limitations, see page 2-11.

For resistance factor "K", equivalent length in feet of pipe, and equivalent flow coefficient "C_v", see pages A-31 and A-32.

<u>Figure 4.3</u>

Table C.1 *Physical properties of water in English units*†

Temp, °F	Specific weight γ, lb/ft³	Density ρ, slugs/ft³	Viscosity μ, lb·s/ft² $10^5\mu$ =	Kinematic viscosity ν, ft²/s $10^5\nu$ =	Surface tension σ, lb/ft 100σ =	Vapor-pressure head p_v/γ, ft	Bulk modulus of elasticity K, lb/in² $10^{-3}K$ =
32	62.42	1.940	3.746	1.931	0.518	0.20	293
40	62.43	1.940	3.229	1.664	0.514	0.28	294
50	62.41	1.940	2.735	1.410	0.509	0.41	305
60	62.37	1.938	2.359	1.217	0.504	0.59	311
70	62.30	1.936	2.050	1.059	0.500	0.84	320
80	62.22	1.934	1.799	0.930	0.492	1.17	322
90	62.11	1.931	1.595	0.826	0.486	1.61	323
100	62.00	1.927	1.424	0.739	0.480	2.19	327
110	61.86	1.923	1.284	0.667	0.473	2.95	331
120	61.71	1.918	1.168	0.609	0.465	3.91	333
130	61.55	1.913	1.069	0.558	0.460	5.13	334
140	61.38	1.908	0.981	0.514	0.454	6.67	330
150	61.20	1.902	0.905	0.476	0.447	8.58	328
160	61.00	1.896	0.838	0.442	0.441	10.95	326
170	60.80	1.890	0.780	0.413	0.433	13.83	322
180	60.58	1.883	0.726	0.385	0.426	17.33	313
190	60.36	1.876	0.678	0.362	0.419	21.55	313
200	60.12	1.868	0.637	0.341	0.412	26.59	308
212	59.83	1.860	0.593	0.319	0.404	33.90	300

† This table was compiled primarily from Hydraulic Models, *ASCE Man. Eng. Pract.* 25, 1942.

Table C.2 *Physical properties of water in SI units*

Temp, °C	Specific weight γ, N/m³	Density ρ, kg/m³	Viscosity μ, kg/m·s $10^3\mu$ =	Kinematic viscosity ν, m²/s $10^6\nu$ =	Surface tension σ, N/m 100σ =	Vapor-pressure head p_v/γ, m	Bulk modulus of elasticity K, N/m² $10^{-7}K$ =
0	9805	999.9	1.792	1.792	7.62	0.06	204
5	9806	1000.0	1.519	1.519	7.54	0.09	206
10	9803	999.7	1.308	1.308	7.48	0.12	211
15	9798	999.1	1.140	1.141	7.41	0.17	214
20	9789	998.2	1.005	1.007	7.36	0.25	220
25	9779	997.1	0.894	0.897	7.26	0.33	222
30	9767	995.7	0.801	0.804	7.18	0.44	223
35	9752	994.1	0.723	0.727	7.10	0.58	224
40	9737	992.2	0.656	0.661	7.01	0.76	227
45	9720	990.2	0.599	0.605	6.92	0.98	229
50	9697	988.1	0.549	0.556	6.82	1.26	230
55	9679	985.7	0.506	0.513	6.74	1.61	231
60	9658	983.2	0.469	0.477	6.68	2.03	228
65	9635	980.6	0.436	0.444	6.58	2.56	226
70	9600	977.8	0.406	0.415	6.50	3.20	225
75	9589	974.9	0.380	0.390	6.40	3.96	223
80	9557	971.8	0.357	0.367	6.30	4.86	221
85	9529	968.6	0.336	0.347	6.20	5.93	217
90	9499	965.3	0.317	0.328	6.12	7.18	216
95	9469	961.9	0.299	0.311	6.02	8.62	211
100	9438	958.4	0.284	0.296	5.94	10.33	207