STRENGTH CALCULATIONS FOR SELF SUPPORTING ANTENNA MASTS

BY GEORGE ZURBUCHEN K9CC

The purpose of this article is to first show how to calculate the load that a antenna array imposes on it's supporting mast, and second how to select a mast which will support the load.

First some general comments on the effect of antenna design on tower load.

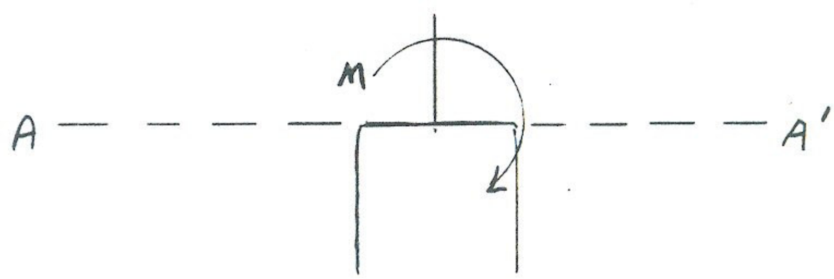
1. The primary consideration is surface area as seen by the wind, <u>not</u> the weight of the antenna.

2. The value used by Hy Gain Electronics is 25.6 lbs force due to wind loading in a 80 mph wind per square foot of antenna area, and can be considered a good standard.

3. The wind load of the antenna is not proportional to the weight of the antenna. For example the Hy Gain TH6DXX is 2.5 lb wind load per lb of antenna weight, while their 15 element 2 meter beam is 3.5 lb of wind load per pound of antenna weight.

The following is a sample problem using a four antenna "christmas tree" array,(see figure A).

The first step in solving the problem is to determine the bending moment, M, around axis A-A' at the anchor point. The anchor point is where the top of the tower meets the bottom of the mast.



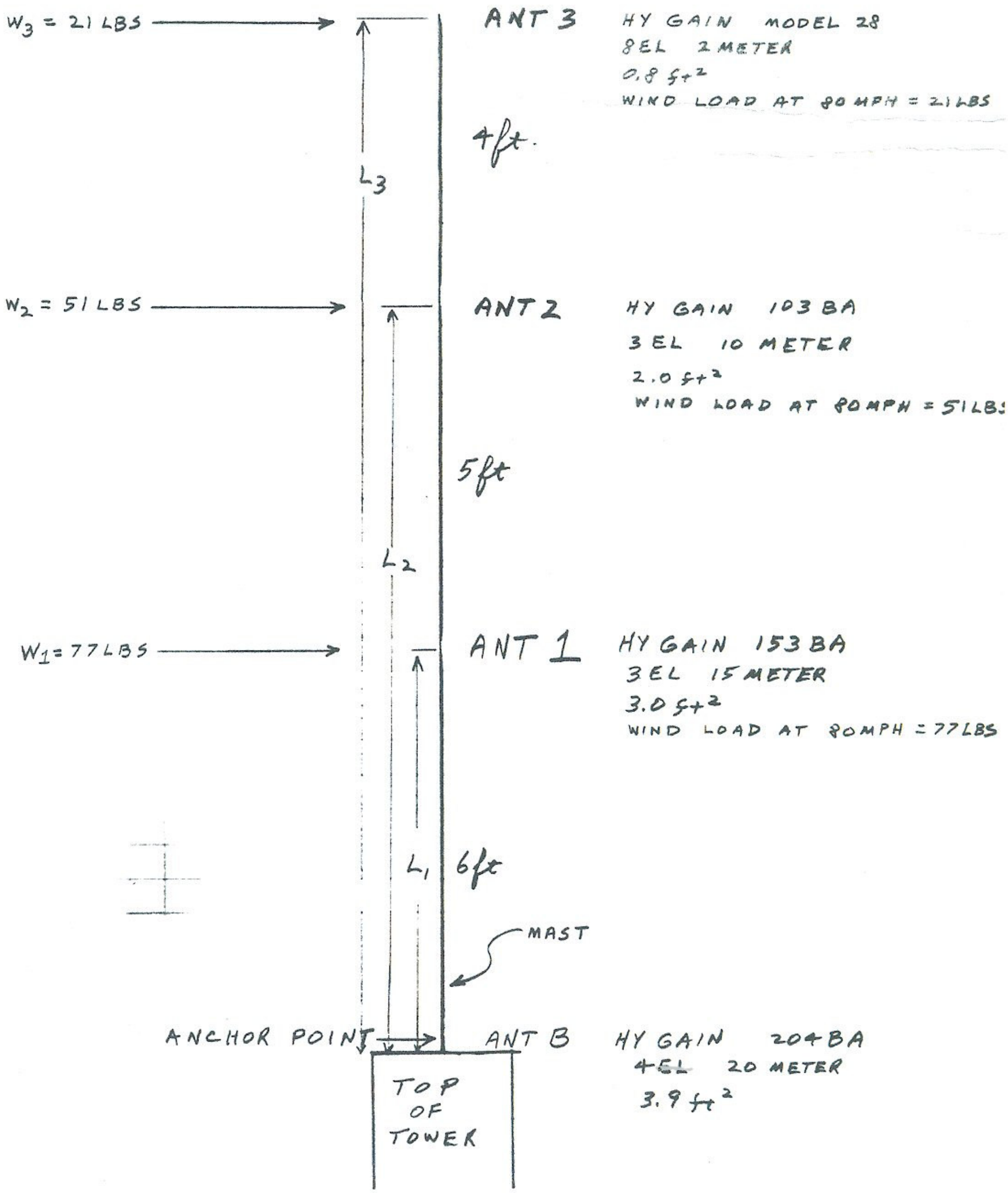
The anchor point could just as well be the bottom of a self supporting ground mounted mast.

Determining the bending moment due to the antennas is done by summing up the wind forces W, times their respective lever arms L. Refer to figure A.

FIGURE A

BY - K9CC

DESCRIPTION FORCE DIAGRAM FOR FOUR ANTENNA ARRAY DATE 10/12/81



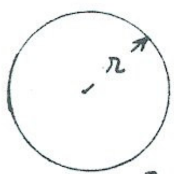
$$M_1 = (W_1) \times (L_1) = 77 \text{ lbs} \times 6 \text{ ft} = 462 \text{ ft lbs}$$
$$M_2 = (W_2) \times (L_2) = 51 \text{ lbs} \times 11 \text{ ft} = 561 \text{ ft lbs}$$
$$M_3 = (W_3) \times (L_3) = 21 \text{ lbs} \times 15 \text{ ft} = 315 \text{ ft lbs}$$

$$M_A = 1338 \text{ ft lbs}$$

Since the 4 el 20 meter is mounted at the "anchor point", the bending moment on the mast is zero because the lever arm is zero. Therefore the 100 lbs of force from the 20 meter beam is imposed on the tower only.

The second step in solving the problem is to calculate the section modulus Z, of the mast.

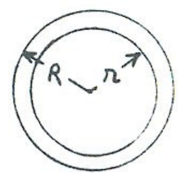
SOLID ROD



where r = radius of rod.

$$Z = \frac{\pi r^3}{4}$$

PIPE



where r = Inner diameter $\div 2$

where R = Outer diameter $\div 2$

$$Z = \frac{\pi}{4R}(R^4 - r^4)$$

For common pipe sizes the section modulus can be read from the attached tables 1 and 2. For illustration purposes let's calculate the section modulus using the formula, and then calculate the strength, for 1 1/2 inch schedule 80 "water pipe". From table 1 or 2, we see the dimensions of this kind of pipe are 1.9 inches O.D. and 1.5 inches I.D.

$$Z = \frac{\pi}{4R}(R^4 - r^4)$$

where $R = \text{O.D.} \div 2 = \frac{1.900}{2} = 0.95$

where $r = \text{I.D} \div 2 = \frac{1.500}{2} = 0.75$

$$Z = \frac{3.1416}{4\,(0.95)}\left(.95^4 - .75^4\right)$$

$$Z = .8267\,(.8145 - .3164)$$

$$Z = .4118 \text{ in}^3$$

The third step is to determine the yield and tensile strength values for the mast material.

First an explanation of yield strength and tensile strength. Yield strength is the load in pounds per square inch that results in permanent deformation, (the mast will be permanently bent). Tensile strength is the load in pounds per square inch that results in the mast actually breaking. Since a bent mast is totally unacceptable, the yield point should be used as the design parameter. However, it is sometimes difficult to learn what the yield strength is for the pipe or tubing in question, since tensile strengths are more commonly quoted.

Ordinary "hardware store" variety water pipe has ASTM designation A53. The tensile strength varies from 45,000 to 60,000 pounds per square inch , and the yield strength from

30,000 to 35,000 pounds per square inch for A53 pipe, depending on the manufacturing method employed. Other higher grade carbon steel pipes have tensile strengths ranging from 45,000 to 85,000 psi.

More exotic alloy steel pipes have tensile strengths varying from 45,000 to 125,000 psi. This includes stainless steel and chrome moly alloys. High price is not necessarily a guarantee of high strength when used as a antenna mast since the desirable quality might be high strength at high temperatures, or corrosion resistance when used in a chemical environment.

Aluminum pipes have greatly varying strengths depending on alloy type and temper. Therefore it is imperative that the alloy, temper, and yield strength be determined before purchasing an expensive aluminum mast. Incidently the high strength aluminum alloys have yield and tensile values that are much closer to each other then the yield and tensile values for mild steel water pipe. This means that when overloaded, the high strength aluminum mast might break instead of bending.

For our calculations we will use steel pipe with a yield strength of 30,000 psi. It is often going to be difficult to determine the exact value for the pipe you are using for a mast, so the 30,000 psi value should be used since it is the lowest value.

The forth step is to calculate the bending moment M, of the selected mast material at which permanent deformation occurs. To do this we use the flexure formula.

$$M = SZ$$

Where:		Units
	M = bending moment	inch lbs
	S = stress	lb/sq in (psi)
	Z = section modulus	cu in

When used in this type of calculation the stress value in the formula is equal to the yield strength of the mast material.

Now solving for M we will determine the maximum allowable bending moment for 1 1/2" Sch 80 pipe.

$$M = SZ = 30{,}000 \text{ lb/sq in} \times 0.412 \text{ cu in} = 12360 \text{ inch lbs}$$

Before we can compare the mast strength calculated above to the bending moment generated by the action of the wind on the antennas, we must add the wind force on the mast itself. First determine the area exposed to the wind by multiplying the mast O.D. times the exposed length of the mast.

$$\frac{1.9\ in}{12\ in/ft} \times 15\,ft = 2.375\,ft^2$$

Now multiply by 25,6 to get the pounds of force generated by an 80 mph wind, and multiply by the lever arm to get the bending moment component due to the mast wind resistance. The lever arm is one half the length of the mast.

$$W_m = 2.375\,ft^2 \times 25.6\ lb/ft^2 = 60.8\,lbs.$$

$$M_M = (W_M) \times (L_M) = 60.8\,lbs \times 7.5\,ft = 456\,ft\,lbs.$$

Add the mast moment to the antenna moment to get the total bending moment.

$$M_T = M_A + M_M = 1338 + 456 = 1794\,ft\,lbs.$$

The value of M_T must be converted to inch lbs to compare to the M value computed by the flexure formula.

1794 ft lbs x 12 inch / ft = 21,528 in lb

1 1/2" schedule 80 pipe is not strong enough because the strength calculated is less then the load.

Strength = 12360 in lb
Load = 21528 in lb

Next try inserting a close fitting solid steel rod into the pipe to fill the center section and in effect make a solid steel rod 1.9 inches in diameter. Using the formula for a solid steel rod the section modulus is.

$$Z = \frac{\pi r^3}{4} = \frac{3.1416\left(\frac{1.9}{2}\right)^3}{4}$$

$$Z = \frac{3.1416\ (.8574)}{4} = .6734\,in^3$$

$$M = SZ = 30{,}000\ lb/in^2 \times .6734\,in^3$$

$$M = 20{,}202\ in\ lb.$$

With the steel rod the mast is still not adequate.

Strength = 20202 in lb
Load = 21528 in lb

The disadvantage of adding a steel rod is that the same calculation must be done at the point where the rod ends, to insure that the resultant bending moment doesn't exceed the strength of the pipe alone at that point.

Let's try 2 1/2" schedule 40 pipe. Keep in mind that a new wind load must be calculated for the mast. Rather then calculate the section modulus note that the value is available in either of the attached pipe tables under the column heading "Section Modulus".

First calculate the wind load due to the mast.

$$\frac{2.875\ in}{12\ in/ft} \times 15\ Ft = 3.594\ ft^2$$

$$W_M = 3.594\ ft^2 \times 25.6\ lb/ft^2 = 92.0\ lbs.$$

$$M_M = W_M \times L_M = 92\ lbs \times 7.5\ ft = 690\ ft\ lbs.$$

$$M_T = M_A + M_M = 1338 + 690 = 2028\ ft\ lbs.$$

$$M_T = 2028\ ft\ lbs \times 12\ \frac{in}{ft} = 24336\ in\ lbs.$$

Next calculate the strength.

M = SZ = 30,000 lbs / sq in x 1.064 cu in = 31920 in lb

The 2 1/2" Sch 40 pipe has adequate strength.

Strength = 31920 in lb
Load = ~~22896~~ 24336 in lb

It should be mentioned that this calculation does not allow for any safety factor other then that which may be built into the yield strength value. There is a slight safety factor built into the mast area calculation since it assumes a "square" frontal area rather then the more streamlined round shape of a pipe.

A useful shortcut can be performed with the pipe tables when comparing pipes of the same material of construction. The proportional strengths and weights can be obtained by simply looking at the values of Section Modulus and Metal Area. These values are directly proportional to the strength and the weight of the pipe in question.

A final calculation can be done to arrive at the total wind load area as applied to the top of the tower. Note that until now the load imposed by antenna B was ignored. This is because it is at the anchor point and therefore imposes no bending moment on the mast. It is however part of the total force applied to the top of the tower.

Ant B	3.9 sq ft
Ant 1	3.0 sq ft
Ant 2	2.0 sq ft
Ant 3	0.8 sq ft
Mast(2 1/2")	3.6 sq ft
Total Area	13.3 sq ft
Total Force	13.3 x 25.6 lb/sq ft = 340.5 lbs force

The Rohn Company specifies a maximum allowable area at the top of a properly guyed tower. These ratings are 6 sq ft for a Rohn 25, and 8 sq ft for a Rohn 45. The area for a TH6DXX alone is 6.1 sq ft! Therefore it is obvious that Rohn has a considerable safety factor based on prevailing amateur practice of exceeding these ratings.

You will notice by looking at the section modulus values that there is a great advantage to going to a larger diameter mast instead of a thicker walled mast. This was also demonstrated in the sample problem we just did. You will get much higher strength per pound of metal with the larger diameter mast then with the thicker wall.

Since Rhon sells a 3" thrust bearing, 2 1/2" schedule 40 steel pipe, is an attractive mast material with it's 2 7/8" actual outside diameter and low cost. Note that common pipe sizes are based on nominal inside diameter. A 14 foot length of 2 1/2" pipe weighs the same as a 10 foot section of Rohn 45.

For example the tower here at K9CC consists of a 75 foot Rohn 45 with a 14 foot 2 1/2" carbon steel pipe mast.

There is a 3" thrust bearing at the top of the tower, a steady bearing made from a pipe flange bolted to a Rohn accessory plate approximately 2 feet below the top of the tower, and the antenna rotator is on a Rohn accessory plate about 4 feet below the top of the tower. The antennas on the mast are a TH6DXX, a dipole for the WARC bands and a 40 meter dipole on the top, 91 feet above the ground. Access to the upper antennas can be accomplished by removing the rotator and lowering the mast into the tower with a fence puller, "come along". The 40 M dipole is on a 5 foot extension of 1 1/2" pipe that was added after the mast was installed.

Table 3. Physical Properties of Pipe*
(Grinnell Co., Inc.)

Nominal pipe size, O.D., in.	Schedule number† a	Schedule number† b	Schedule number† c	Wall thickness, in.	I.D., in.	Inside area, sq in.	Metal area, sq in.	Sq ft outside surface, per ft	Sq ft inside surface, per ft	Weight per ft, lb	Weight of water per ft, lb	Moment of inertia, in.^{4}	Section modulus, in.^{3}	Radius gyration, in.
⅛ 0.405	...	.....	10S	0.049	0.307	0.0740	0.0548	0.106	0.0804	0.186	0.0321	0.00088	0.00437	0.1271
	40	Std	40S	0.068	0.269	0.0568	0.0720	0.106	0.0705	0.245	0.0246	0.00106	0.00525	0.1215
	80	XS	80S	0.095	0.215	0.0364	0.0925	0.106	0.0563	0.315	0.0157	0.00122	0.00600	0.1146
¼ 0.540	...	.....	10S	0.065	0.410	0.1320	0.0970	0.141	0.1073	0.330	0.0572	0.00279	0.01032	0.1694
	40	Std	40S	0.088	0.364	0.1041	0.1250	0.141	0.0955	0.425	0.0451	0.00331	0.01230	0.1628
	80	XS	80S	0.119	0.302	0.0716	0.1574	0.141	0.0794	0.535	0.0310	0.00378	0.01395	0.1547
⅜ 0.675	...	.....	10S	0.065	0.545	0.2333	0.1246	0.177	0.1427	0.423	0.1011	0.00586	0.01737	0.2169
	40	Std	40S	0.091	0.493	0.1910	0.1670	0.177	0.1295	0.568	0.0827	0.00730	0.02160	0.2090
	80	XS	80S	0.126	0.423	0.1405	0.2173	0.177	0.1106	0.739	0.0609	0.00862	0.02554	0.1991
½ 0.840	...	.....	10S	0.083	0.674	0.357	0.1974	0.220	0.1765	0.671	0.1547	0.01431	0.0341	0.2692
	40	Std	40S	0.109	0.622	0.304	0.2503	0.220	0.1628	0.851	0.1316	0.01710	0.0407	0.2613
	80	XS	80S	0.147	0.546	0.2340	0.320	0.220	0.1433	1.088	0.1013	0.02010	0.0478	0.2505
	160	.....	...	0.187	0.466	0.1706	0.383	0.220	0.1220	1.304	0.0740	0.02213	0.0527	0.2402
	...	XXS	...	0.294	0.252	0.0499	0.504	0.220	0.0660	1.714	0.0216	0.02425	0.0577	0.2192
¾ 1.050	...	.....	5S	0.065	0.920	0.665	0.2011	0.275	0.2409	0.684	0.2882	0.02451	0.0467	0.349
	...	.....	10S	0.083	0.884	0.614	0.2521	0.275	0.2314	0.857	0.2661	0.02970	0.0566	0.343
	40	Std	40S	0.113	0.824	0.533	0.333	0.275	0.2157	1.131	0.2301	0.0370	0.0706	0.334
	80	XS	80S	0.154	0.742	0.432	0.435	0.275	0.1943	1.474	0.1875	0.0448	0.0853	0.321
	160	.....	...	0.218	0.614	0.2961	0.570	0.275	0.1607	1.937	0.1284	0.0527	0.1004	0.304
	...	XXS	...	0.308	0.434	0.1479	0.718	0.275	0.1137	2.441	0.0641	0.0579	0.1104	0.284
1 1.315	...	.....	5S	0.065	1.185	1.103	0.2553	0.344	0.310	0.868	0.478	0.0500	0.0760	0.443
	...	.....	10S	0.109	1.097	0.945	0.413	0.344	0.2872	1.404	0.409	0.0757	0.1151	0.428
	40	Std	40S	0.133	1.049	0.864	0.494	0.344	0.2746	1.679	0.374	0.0874	0.1329	0.421
	80	XS	80S	0.179	0.957	0.719	0.639	0.344	0.2520	2.172	0.311	0.1056	0.1606	0.407
	160	.....	...	0.250	0.815	0.522	0.836	0.344	0.2134	2.844	0.2261	0.1252	0.1903	0.387
	...	XXS	...	0.358	0.599	0.2818	1.076	0.344	0.1570	3.659	0.1221	0.1405	0.2137	0.361
1¼ 1.660	...	.....	5S	0.065	1.530	1.839	0.326	0.434	0.401	1.107	0.797	0.1038	0.1250	0.564
	...	.....	10S	0.109	1.442	1.633	0.531	0.434	0.378	1.805	0.707	0.1605	0.1934	0.550
	40	Std	40S	0.140	1.380	1.496	0.669	0.434	0.361	2.273	0.648	0.1948	0.2346	0.540
	80	XS	80S	0.191	1.278	1.283	0.881	0.434	0.335	2.997	0.555	0.2418	0.2913	0.524
1¼ 1.066	160	.....	...	0.250	1.160	1.057	1.107	0.434	0.304	3.765	0.458	0.2839	0.342	0.506
	...	XXS	...	0.382	0.896	0.631	1.534	0.434	0.2346	5.214	0.2732	0.341	0.411	0.472
1½ 1.900	...	.....	5S	0.065	1.770	2.461	0.375	0.497	0.463	1.274	1.067	0.1580	0.1663	0.649
	...	.....	10S	0.109	1.682	2.222	0.613	0.497	0.440	2.085	0.962	0.2469	0.2599	0.634
	40	Std	40S	0.145	1.610	2.036	0.799	0.497	0.421	2.718	0.882	0.310	0.326	0.623
	80	XS	80S	0.200	1.500	1.767	1.068	0.497	0.393	3.631	0.765	0.391	0.412	0.605
	160	.....	...	0.281	1.338	1.406	1.429	0.497	0.350	4.859	0.608	0.483	0.508	0.581
	...	XXS	...	0.400	1.100	0.950	1.885	0.497	0.288	6.408	0.412	0.568	0.598	0.549
2 2.375	...	.....	5S	0.065	2.245	3.96	0.472	0.622	0.588	1.604	1.716	0.315	0.2652	0.817
	...	.....	10S	0.109	2.157	3.65	0.776	0.622	0.565	2.638	1.582	0.499	0.420	0.802
	40	Std	40S	0.154	2.067	3.36	1.075	0.622	0.541	3.653	1.455	0.666	0.561	0.787
	80	XS	80S	0.218	1.939	2.953	1.477	0.622	0.508	5.022	1.280	0.868	0.731	0.766
	160	.....	...	0.343	1.689	2.240	2.190	0.622	0.442	7.444	0.971	1.163	0.979	0.729
	...	XXS	...	0.436	1.503	1.774	2.656	0.622	0.393	9.029	0.769	1.312	1.104	0.703
2½ 2.875	...	.....	5S	0.083	2.709	5.76	0.728	0.753	0.709	2.475	2.499	0.710	0.494	0.988
	...	.....	10S	0.120	2.635	5.45	1.039	0.753	0.690	3.531	2.361	0.988	0.687	0.975
	40	Std	40S	0.203	2.469	4.79	1.704	0.753	0.646	5.793	2.076	1.530	1.064	0.947
	80	XS	80S	0.276	2.323	4.24	2.254	0.753	0.608	7.661	1.837	1.925	1.339	0.924
	160	.....	...	0.375	2.125	3.55	2.945	0.753	0.556	10.01	1.535	2.353	1.637	0.894
	...	XXS	...	0.552	1.771	2.464	4.03	0.753	0.464	13.70	1.067	2.872	1.998	0.844
3 3.500	...	.....	5S	0.083	3.334	8.73	0.891	0.916	0.873	3.03	3.78	1.301	0.744	1.208
	...	.....	10S	0.120	3.260	8.35	1.274	0.916	0.853	4.33	3.61	1.822	1.041	1.196
	40	Std	40S	0.216	3.068	7.39	2.228	0.916	0.803	7.58	3.20	3.02	1.724	1.164
	80	XS	80S	0.300	2.900	6.61	3.02	0.916	0.759	10.25	2.864	3.90	2.226	1.136
	160	.....	...	0.437	2.626	5.42	4.21	0.916	0.687	14.32	2.348	5.03	2.876	1.094
	...	XXS	...	0.600	2.300	4.15	5.47	0.916	0.602	18.58	1.801	5.99	3.43	1.047
3½ 4.000	...	.....	5S	0.083	3.834	11.55	1.021	1.047	1.004	3.47	5.01	1.960	0.980	1.385
	...	.....	10S	0.120	3.760	11.10	1.463	1.047	0.984	4.97	4.81	2.756	1.378	1.372
	40	Std	40S	0.226	3.548	9.89	2.680	1.047	0.929	9.11	4.28	4.79	2.394	1.337
	80	XS	80S	0.318	3.364	8.89	3.68	1.047	0.881	12.51	3.85	6.28	3.14	1.307
4 4.500	...	.....	5S	0.083	4.334	14.75	1.152	1.178	1.135	3.92	6.40	2.811	1.249	1.562
	...	.....	10S	0.120	4.260	14.25	1.651	1.178	1.115	5.61	6.17	3.96	1.762	1.549
	40	Std	40S	0.237	4.026	12.73	3.17	1.178	1.054	10.79	5.51	7.23	3.21	1.510
	80	XS	80S	0.337	3.826	11.50	4.41	1.178	1.002	14.98	4.98	9.61	4.27	1.477
	120	.....	...	0.437	3.626	10.33	5.58	1.178	0.949	18.96	4.48	11.65	5.18	1.445
	160	.....	...	0.531	3.438	9.28	6.62	1.178	0.900	22.51	4.02	13.27	5.90	1.416
	...	XXS	...	0.674	3.152	7.80	8.10	1.178	0.825	27.54	3.38	15.29	6.79	1.374

* See footnote at end of table.
† See footnote at end of table.

PROPERTIES OF PIPE

Pipe Size and Outside Diam.	Sch. No.	Nominal Wall	d Inside Diam. Inches	t Wall Thickness Inches	A_I Inside Area Inches²	A_M Metal Area Inches²	I_P Moment of Inertia Inches⁴	S_m Section Modulus Inches³	Curvature Factors K and β	Short Radius Elbow	Long Radius Elbow	Radius of Curvature Nominal Pipe Diameters 3	4	5	6	8	10
1" 1.315"	40	Std.	1.049	0.133	0.864	0.494	0.0874	0.133	K	4.20	2.31	1.52	1.31	1.20	1.13	1.08	1.05
									β	1.63	1.18	0.87	0.89	0.93	0.96	0.97	0.98
	80	XS	0.957	0.179	0.719	0.639	0.1056	0.161	K	..	1.95	1.26	1.15	1.10	1.06	1.04	1.02
									β	..	0.93	0.91	0.95	0.97	0.98	0.99	0.99
	160		0.815	0.250	0.522	0.836	0.1252	0.190	K	..	1.40	1.10	1.06	1.04	1.03	1.02	1.01
									β	..	0.87	0.97	0.98	0.99	0.99	0.99	1.00
		XXS	0.599	0.358	0.282	1.076	0.1405	0.214	K	..	1.13	1.03	1.02	1.01	1.01	1.00	1.00
									β	..	0.96	0.99	0.99	1.00	1.00	1.00	1.00
1¼" 1.660"	40	Std.	1.380	0.140	1.496	0.669	0.1948	0.235	K	5.28	3.58	1.82	1.48	1.31	1.22	1.12	1.08
									β	1.97	1.42	0.90	0.86	0.89	0.93	0.96	0.97
	80	XS	1.278	0.191	1.283	0.881	0.2418	0.291	K	..	3.33	1.73	1.42	1.28	1.19	1.11	1.07
									β	..	1.35	0.89	0.86	0.91	0.94	0.96	0.98
	160		1.160	0.250	1.057	1.107	0.2839	0.342	K	..	1.77	1.20	1.12	1.08	1.05	1.03	1.02
									β	..	0.89	0.93	0.96	0.97	0.98	0.99	0.99
		XXS	0.896	0.382	0.631	1.534	0.3411	0.411	K	..	1.23	1.06	1.03	1.02	1.02	1.01	1.00
									β	..	0.92	0.98	0.99	0.99	0.99	1.00	1.00
1½" 1.900"	40	Std.	1.610	0.145	2.036	0.799	0.3099	0.326	K	5.60	3.84	1.94	1.55	1.36	1.25	1.14	1.09
									β	2.05	1.50	0.92	0.87	0.88	0.91	0.95	0.97
	80	XS	1.500	0.200	1.767	1.068	0.3912	0.412	K	3.93	2.59	1.45	1.26	1.17	1.12	1.07	1.04
									β	1.54	1.09	0.86	0.91	0.94	0.96	0.98	0.99
	160		1.338	0.281	1.406	1.429	0.4826	0.508	K	..	1.74	1.20	1.11	1.07	1.05	1.03	1.02
									β	..	0.89	0.93	0.96	0.98	0.98	0.99	0.99
		XXS	1.100	0.400	0.950	1.885	0.5678	0.598	K	..	1.49	1.13	1.07	1.05	1.03	1.02	1.01
									β		0.86	0.96	0.98	0.98	0.99	0.99	1.00
2" 2.375"	40	Std.	2.067	0.154	3.356	1.075	0.6657	0.561	K	6.14	4.34	2.18	1.69	1.45	1.32	1.18	1.12
									β	2.22	1.70	0.97	0.88	0.86	0.89	0.94	0.96
	80	XS	1.939	0.218	2.953	1.477	0.8679	0.731	K	4.34	2.88	1.55	1.32	1.20	1.15	1.08	1.05
									β	1.70	1.16	0.87	0.89	0.93	0.95	0.97	0.98
	160		1.689	0.343	2.240	2.190	1.1626	0.979	K	..	1.70	1.18	1.10	1.07	1.05	1.03	1.02
									β	..	0.88	0.94	0.97	0.98	0.98	0.99	0.99
		XXS	1.503	0.436	1.774	2.656	1.312	1.104	K	..	1.37	1.10	1.05	1.04	1.02	1.01	1.01
									β	..	0.88	0.97	0.98	0.99	0.99	1.00	1.00
2½" 2.875"	40	Std.	2.469	0.203	4.788	1.704	1.530	1.064	K	5.55	3.82	1.92	1.54	1.35	1.25	1.14	1.08
									β	2.04	1.49	0.92	0.87	0.88	0.91	0.95	0.97
	80	XS	2.323	0.276	4.238	2.254	1.925	1.339	K	4.00	2.63	1.47	1.27	1.18	1.12	1.07	1.04
									β	1.54	1.12	0.86	0.91	0.94	0.96	0.98	0.99
	160		2.125	0.375	3.547	2.945	2.353	1.637	K	..	1.84	1.23	1.13	1.08	1.06	1.03	1.02
									β	..	0.90	0.93	0.96	0.97	0.98	0.99	0.99
		XXS	1.771	0.552	2.464	4.028	2.872	1.998	K	..	1.31	1.08	1.04	1.03	1.02	1.01	1.01
									β	..	0.90	0.97	0.99	0.99	0.99	1.00	1.00
3" 3.500"	40	Std.	3.068	0.216	7.393	2.228	3.017	1.724	K	6.32	4.53	2.25	1.75	1.49	1.35	1.20	1.13
									β	2.30	1.75	0.98	0.89	0.86	0.88	0.93	0.96
	80	XS	2.900	0.300	6.605	3.016	3.897	2.226	K	4.61	3.08	1.62	1.36	1.23	1.17	1.09	1.06
									β	1.76	1.25	0.87	0.88	0.92	0.94	0.97	0.98
	160		2.626	0.437	5.416	4.205	5.033	2.876	K	..	1.95	1.26	1.15	1.09	1.06	1.04	1.02
									β	..	0.93	0.91	0.95	0.97	0.98	0.99	0.99
		XXS	2.300	0.600	4.155	5.466	5.993	3.425	K	..	1.21	1.05	1.03	1.02	1.01	1.01	1.00
									β	..	0.93	0.98	0.99	0.99	1.00	1.00	1.00
3½" 4.000"	40	Std.	3.548	0.226	9.89	2.68	4.788	2.39	K	6.64	4.85	2.42	1.86	1.58	1.40	1.23	1.15
									β	2.40	1.91	1.04	0.91	0.87	0.87	0.92	0.95