Table A3.6. *Recommended hole size limits before threading for different lengths of engagement, standard Unified and some UNS threads, class 3B (based on table 3.10[a])*

Nominal size in inches and threads per inch	Series designation	Minor diameter of internal threads				Recommended hole size limits for different lengths of engagement							
		Min	Percent basic thread height [b]	Max [c]	Percent basic thread height [b]	To and including 0.33*D*		Above 0.33*D* thru 0.67*D*		Above 0.67*D* thru 1.5*D*		Above 1.5*D* thru 3*D*	
						Min	Max	Min	Max	Min	Max	Min	Max
1	2	3	4	5	6	7	8	9	10	11	12	13	14
.060–80 or No. 0–80	UNF	*in* 0.0465	83.1	*in* 0.0514	53.0	*in* 0.0465	*in* 0.0500	*in* 0.0479	*in* 0.0514	*in* 0.0479	*in* 0.0514	*in* 0.0479	*in* 0.0514
.073–64 or No. 1–64	UNC	.0561	83.3	.0623	52.7	.0561	.0599	.0580	.0618	.0585	.0623	.0585	.0623
.073–72 or No. 1–72	UNF	.0580	83.1	.0635	52.7	.0580	.0613	.0596	.0629	.0602	.0635	.0602	.0635
.086–56 or No. 2–56	UNC	.0667	83.2	.0737	53.0	.0667	.0705	.0686	.0724	.0699	.0737	.0699	.0737
.086–64 or No. 2–64	UNF	.0691	83.3	.0753	52.7	.0691	.0724	.0707	.0740	.0720	.0753	.0720	.0753
.099–48 or No. 3–48	UNC	.0764	83.5	.0845	53.6	.0764	.0804	.0785	.0825	.0805	.0845	.0806	.0846
.099–56 or No. 3–56	UNF	.0797	83.2	.0865	53.9	.0797	.0831	.0814	.0848	.0831	.0865	.0833	.0867
.112–40 or No. 4–40	UNC	.0849	83.4	.0939	55.7	.0849	.0894	.0871	.0916	.0894	.0939	.0902	.0947
.112–48 or No. 4–48	UNF	.0894	83.5	.0968	56.2	.0894	.0931	.0912	.0949	.0931	.0968	.0939	.0976
.125–40 or No. 5–40	UNC	.0979	83.4	.1062	57.9	.0979	.1020	.1000	.1041	.1021	.1062	.1036	.1077
.125–44 or No. 5–44	UNF	.1004	83.3	.1079	57.9	.1004	.1041	.1023	.1060	.1042	.1079	.1057	.1094
.138–32 or No. 6–32	UNC	.1040	83.8	.1140	59.1	.1040	.1091	.1066	.1115	.1091	.1140	.1115	.1164
.138–40 or No. 6–40	UNF	.1110	83.1	.1186	59.7	.1110	.1148	.1128	.1167	.1147	.1186	.1166	.1205
.164–32 or No. 8–32	UNC	.1300	83.8	.1389	61.8	.1300	.1345	.1324	.1367	.1346	.1389	.1367	.1410
.164–36 or No. 8–36	UNF	.1340	83.1	.1416	62.1	.1340	.1377	.1359	.1397	.1378	.1416	.1397	.1435
.190–24 or No. 10–24	UNC	.1450	83.1	.1555	63.7	.1450	.1502	.1475	.1528	.1502	.1555	.1528	.1581
.190–32 or No. 10–32	UNF	.1560	83.8	.1641	63.8	.1560	.1601	.1582	.1621	.1602	.1641	.1622	.1661
.216–24 or No. 12–24	UNC	.1710	83.1	.1807	65.2	.1710	.1758	.1733	.1782	.1758	.1807	.1782	.1831
.216–28 or No. 12–28	UNF	.1770	84.1	.1857	65.3	.1770	.1815	.1794	.1836	.1815	.1857	.1836	.1878
.216–32 or No. 12–32	UNEF	.1820	83.8	.1895	65.3	.1820	.1858	.1841	.1877	.1859	.1895	.1877	.1913
.250–20	UNC	.1960	83.1	.2067	66.7	.1960	.2013	.1986	.2040	.2013	.2067	.2040	.2094
.250–28	UNF	.2110	84.1	.2190	66.8	.2110	.2152	.2131	.2171	.2150	.2190	.2169	.2209
.250–32	UNEF	.2160	83.8	.2229	66.8	.2160	.2196	.2172	.2212	.2189	.2229	.2206	.2246
.250–36	UNS	.2200	83.1	.2258	67.1	.2200	.2229	.2203	.2243	.2218	.2258	.2233	.2273
.3125–18	UNC	.2520	83.8	.2630	68.6	.2520	.2577	.2551	.2604	.2577	.2630	.2604	.2657
.3125–20	20UN	.2580	83.9	.2680	68.5	.2580	.2632	.2608	.2656	.2632	.2680	.2656	.2704
.3125–24	UNF	.2670	84.1	.2754	68.5	.2670	.2714	.2694	.2734	.2714	.2754	.2734	.2774
.3125–28	28UN	.2740	83.0	.2807	68.5	.2740	.2772	.2749	.2789	.2767	.2807	.2784	.2824
.3125–32	UNEF	.2790	82.5	.2847	68.5	.2790	.2817	.2792	.2832	.2807	.2847	.2822	.2862
.3125–36	UNS	.2820	84.5	.2877	68.7	.2820	.2850	.2823	.2863	.2837	.2877	.2850	.2890
.375–16	UNC	.3070	83.8	.3182	70.0	.3070	.3127	.3101	.3155	.3128	.3182	.3155	.3209
.375–20	20UN	.3210	83.1	.3297	69.7	.3210	.3253	.3231	.3275	.3253	.3297	.3275	.3319
.375–24	UNF	.3300	83.1	.3372	69.8	.3300	.3336	.3314	.3354	.3332	.3372	.3351	.3391
.375–28	28UN	.3360	84.1	.3426	69.8	.3360	.3395	.3370	.3410	.3386	.3426	.3402	.3442
.375–32	UNEF	.3410	83.8	.3469	69.2	.3410	.3441	.3415	.3455	.3429	.3469	.3444	.3484
.375–36	UNS	.3450	83.1	.3501	69.0	.3450	.3475	.3450	.3490	.3461	.3501	.3474	.3514
.4375–14	UNC	.3600	83.5	.3717	70.9	.3600	.3660	.3630	.3688	.3659	.3717	.3688	.3746
.4375–16	16UN	.3700	83.1	.3800	70.8	.3700	.3749	.3723	.3774	.3749	.3800	.3774	.3825
.4375–20	UNF	.3830	83.9	.3916	70.7	.3830	.3875	.3855	.3896	.3875	.3916	.3896	.3937
.4375–28	UNEF	.3990	83.0	.4051	69.8	.3990	.4020	.3995	.4035	.4011	.4051	.4027	.4067
.4375–32	32UN	.4040	82.5	.4094	69.2	.4040	.4066	.4040	.4080	.4054	.4094	.4069	.4109

.500–12	UNS	.4100	83.1	.4223	71.8	.4100	.4161	.4129	.4192	.4160	.4223	.4192	.4255
.500–13	UNC	.4170	83.1	.4284	71.7	.4170	.4225	.4196	.4254	.4226	.4284	.4255	.4313
.500–16	16UN	.4320	83.8	.4419	71.6	.4320	.4371	.4347	.4395	.4371	.4419	.4395	.4443
.500–20	UNF	.4460	83.1	.4537	71.3	.4460	.4498	.4477	.4517	.4497	.4537	.4516	.4556
.500–28	UNEF	.4610	84.1	.4676	69.8	.4610	.4645	.4620	.4660	.4636	.4676	.4652	.4692
.500–32	32UN	.4660	83.8	.4719	69.2	.4660	.4691	.4665	.4705	.4679	.4719	.4694	.4734
.5625–12	UNC	.4720	83.6	.4843	72.2	.4720	.4783	.4753	.4813	.4783	.4843	.4813	.4873
.5625–16	16UN	.4950	83.1	.5040	72.1	.4950	.4994	.4971	.5017	.4994	.5040	.5017	.5063
.5625–18	UNF	.5020	83.8	.5106	71.9	.5020	.5065	.5045	.5086	.5065	.5106	.5086	.5127
.5625–20	20UN	.5080	83.9	.5162	71.3	.5080	.5123	.5102	.5142	.5122	.5162	.5141	.5181
.5625–24	UNEF	.5170	84.1	.5244	70.4	.5170	.5209	.5186	.5226	.5204	.5244	.5221	.5261
.5625–28	28UN	.5240	83.0	.5301	69.8	.5240	.5270	.5245	.5285	.5261	.5301	.5277	.5317
.5625–32	32UN	.5290	82.5	.5344	69.2	.5290	.5316	.5290	.5330	.5304	.5344	.5319	.5359
.625–11	UNC	.5270	83.0	.5391	72.7	.5270	.5328	.5298	.5360	.5329	.5391	.5360	.5422
.625–12	12UN	.5350	83.1	.5463	72.7	.5350	.5406	.5377	.5435	.5405	.5463	.5434	.5492
.625–16	16UN	.5570	83.8	.5662	72.4	.5570	.5617	.5596	.5640	.5618	.5662	.5640	.5684
.625–18	UNF	.5650	83.1	.5730	72.1	.5650	.5690	.5669	.5710	.5689	.5730	.5710	.5751
.625–20	20UN	.5710	83.1	.5787	71.3	.5710	.5748	.5727	.5767	.5747	.5787	.5766	.5806
.625–24	UNEF	.5800	83.1	.5869	70.4	.5800	.5834	.5811	.5851	.5829	.5869	.5846	.5886
.625–28	28UN	.5860	84.1	.5926	69.8	.5860	.5895	.5870	.5910	.5886	.5926	.5902	.5942
.625–32	32UN	.5910	83.8	.5969	69.2	.5910	.5941	.5915	.5955	.5929	.5969	.5944	.5984
.6875–12	12UN	.5970	83.6	.6085	73.0	.5970	.6029	.6001	.6057	.6029	.6085	.6057	.6113
.6875–16	16UN	.6200	83.1	.6284	72.8	.6200	.6241	.6219	.6262	.6241	.6284	.6263	.6306
.6875–18	UNS	.6270	83.8	.6355	72.1	.6270	.6315	.6294	.6335	.6314	.6355	.6335	.6376
.6875–20	20UN	.6330	83.9	.6412	71.3	.6330	.6373	.6352	.6392	.6372	.6412	.6391	.6431
.6875–24	UNEF	.6420	84.1	.6494	70.4	.6420	.6459	.6436	.6476	.6454	.6494	.6471	.6511
.6875–28	28UN	.6490	83.0	.6551	69.8	.6490	.6520	.6495	.6535	.6511	.6551	.6527	.6567
.6875–32	32UN	.6540	82.5	.6594	69.2	.6540	.6566	.6540	.6580	.6554	.6594	.6569	.6609
.750–10	UNC	.6420	83.1	.6545	73.5	.6420	.6481	.6449	.6513	.6481	.6545	.6513	.6577
.750–12	12UN	.6600	83.1	.6707	73.3	.6600	.6652	.6626	.6680	.6653	.6707	.6680	.6734
.750–16	UNF	.6820	83.8	.6908	72.9	.6820	.6866	.6844	.6887	.6865	.6908	.6886	.6929
.750–18	UNS	.6900	83.1	.6980	72.1	.6900	.6940	.6919	.6960	.6939	.6980	.6960	.7001
.750–20	UNEF	.6960	83.1	.7037	71.3	.6960	.6998	.6977	.7017	.6997	.7037	.7016	.7056
.750–28	28UN	.7110	84.1	.7176	69.8	.7110	.7145	.7120	.7160	.7136	.7176	.7152	.7192
.750–32	32UN	.7160	83.8	.7219	69.2	.7160	.7191	.7165	.7205	.7179	.7219	.7194	.7234
.8125–12	12UN	.7220	83.6	.7329	73.5	.7220	.7276	.7250	.7303	.7276	.7329	.7303	.7356
.8125–16	16UN	.7450	83.1	.7533	72.9	.7450	.7491	.7469	.7512	.7490	.7533	.7511	.7554
.8125–18	UNS	.7520	83.8	.7605	72.1	.7520	.7565	.7544	.7585	.7564	.7605	.7585	.7626
.8125–20	UNEF	.7580	83.9	.7662	71.3	.7580	.7623	.7602	.7642	.7622	.7662	.7641	.7681
.8125–28	28UN	.7740	83.0	.7801	69.8	.7740	.7770	.7745	.7785	.7761	.7801	.7777	.7817
.8125–32	32UN	.7790	82.5	.7844	69.2	.7790	.7816	.7790	.7830	.7804	.7844	.7819	.7859
.875–9	UNC	.7550	83.1	.7681	74.1	.7550	.7614	.7580	.7647	.7614	.7681	.7647	.7714
.875–12	12UN	.7850	83.1	.7952	73.7	.7850	.7900	.7874	.7926	.7900	.7952	.7926	.7978
.875–14	UNF	.7980	83.0	.8068	73.5	.7980	.8022	.8000	.8045	.8023	.8068	.8045	.8090
.875–16	16UN	.8070	83.8	.8158	72.9	.8070	.8116	.8094	.8137	.8115	.8158	.8136	.8179
.875–18	UNS	.8150	83.1	.8230	72.1	.8150	.8190	.8169	.8210	.8189	.8230	.8210	.8251
.875–20	UNEF	.8210	83.1	.8287	71.3	.8210	.8248	.8227	.8267	.8247	.8287	.8266	.8306
.875–28	28UN	.8360	84.1	.8426	69.8	.8360	.8395	.8370	.8410	.8386	.8426	.8402	.8442
.875–32	32UN	.8410	83.8	.8469	69.2	.8410	.8441	.8415	.8455	.8429	.8469	.8444	.8484
.9375–12	12UN	.8470	83.6	.8575	73.9	.8470	.8524	.8499	.8550	.8524	.8575	.8550	.8601
.9375–16	16UN	.8700	83.1	.8783	72.9	.8700	.8741	.8719	.8762	.8740	.8783	.8761	.8804
.9375–20	UNEF	.8830	83.9	.8912	71.3	.8830	.8873	.8852	.8892	.8872	.8912	.8891	.8931
.9375–28	28UN	.8990	83.0	.9051	69.8	.8990	.9020	.8995	.9035	.9011	.9051	.9027	.9067
.9375–32	32UN	.9040	82.5	.9094	69.2	.9040	.9066	.9040	.9080	.9054	.9094	.9069	.9109
1.000–8	UNC	.8650	83.1	.8797	74.1	.8650	.8722	.8684	.8759	.8722	.8797	.8760	.8835
1.000–12	UNF	.9100	83.1	.9198	74.1	.9100	.9148	.9123	.9173	.9148	.9198	.9173	.9223
1.000–14	UNS	.9230	83.0	.9315	73.8	.9230	.9271	.9249	.9293	.9271	.9315	.9293	.9337
1.000–16	16UN	.9320	83.8	.9408	72.9	.9320	.9366	.9344	.9387	.9365	.9408	.9386	.9429
1.000–18	UNS	.9400	83.1	.9480	72.1	.9400	.9440	.9419	.9460	.9439	.9480	.9460	.9501
1.000–20	UNEF	.9460	83.1	.9537	71.3	.9460	.9498	.9477	.9517	.9497	.9537	.9516	.9556
1.000–28	28UN	.9610	84.1	.9676	69.8	.9610	.9645	.9620	.9660	.9636	.9676	.9652	.9692
1.000–32	32UN	.9660	83.8	.9719	69.2	.9660	.9691	.9665	.9705	.9679	.9719	.9694	.9734

See footnotes at end of table.

TABLE A3.6. *Recommended hole size limits before threading for different lengths of engagement, standard Unified and some UNS threads, class 3B (based on table 3.10*[a]*)*—Continued

Nominal size in inches and threads per inch	Series designation	Minor diameter of internal threads				Recommended hole size limits for different lengths of engagement							
		Min	Percent basic thread height [b]	Max [c]	Percent basic thread height [b]	To and including 0.33*D*		Above 0.33*D* thru 0.67*D*		Above 0.67*D* thru 1.5*D*		Above 1.5*D* thru 3*D*	
						Min	Max	Min	Max	Min	Max	Min	Max
1	2	3	4	5	6	7	8	9	10	11	12	13	14
		in		*in*		*in*	*in*	*in*	*in*	*in*	*in*	*in*	*in*
1.0625–8	8UN	.9270	83.4	.9422	74.1	.9270	.9347	.9309	.9384	.9347	.9422	.9385	.9460
1.0625–12	12UN	.9720	83.6	.9823	74.1	.9720	.9773	.9748	.9798	.9773	.9823	.9798	.9848
1.0625–14	UNS	.9850	83.5	.9940	73.8	.9850	.9896	.9874	.9918	.9896	.9940	.9918	.9962
1.0625–16	16UN	.9950	83.1	1.0033	72.9	.9950	.9991	.9969	1.0012	.9990	1.0033	1.0011	1.0054
1.0625–18	UNEF	1.0020	83.8	1.0105	72.1	1.0020	1.0065	1.0044	1.0085	1.0064	1.0105	1.0085	1.0126
1.0625–20	20UN	1.0080	83.9	1.0162	71.3	1.0080	1.0123	1.0102	1.0142	1.0122	1.0162	1.0141	1.0181
1.0625–28	28UN	1.0240	83.0	1.0301	69.8	1.0240	1.0270	1.0245	1.0285	1.0261	1.0301	1.0277	1.0317
1.125–7	UNC	0.9700	83.5	0.9875	74.1	0.9700	0.9790	0.9747	0.9833	0.9789	0.9875	0.9832	0.9918
1.125–8	8UN	.9900	83.1	1.0047	74.1	.9900	.9972	.9934	1.0009	.9972	1.0047	1.0010	1.0085
1.125–12	UNF	1.0350	83.1	1.0448	74.1	1.0350	1.0398	1.0373	1.0423	1.0398	1.0448	1.0423	1.0473
1.125–16	16UN	1.0570	83.8	1.0658	72.9	1.0570	1.0616	1.0594	1.0637	1.0615	1.0658	1.0636	1.0679
1.125–18	UNEF	1.0650	83.1	1.0730	72.1	1.0650	1.0690	1.0669	1.0710	1.0689	1.0730	1.0710	1.0751
1.125–20	20UN	1.0710	83.1	1.0787	71.3	1.0710	1.0748	1.0727	1.0767	1.0747	1.0787	1.0766	1.0806
1.125–28	28UN	1.0860	84.1	1.0926	69.8	1.0860	1.0895	1.0870	1.0910	1.0886	1.0926	1.0902	1.0942
1.1875–8	8UN	1.0520	83.4	1.0672	74.1	1.0520	1.0597	1.0559	1.0634	1.0597	1.0672	1.0635	1.0710
1.1875–12	12UN	1.0970	83.6	1.1073	74.1	1.0970	1.1023	1.0998	1.1048	1.1023	1.1073	1.1048	1.1098
1.1875–16	16UN	1.1200	83.1	1.1283	72.9	1.1200	1.1241	1.1219	1.1262	1.1240	1.1283	1.1261	1.1304
1.1875–18	UNEF	1.1270	83.8	1.1355	72.1	1.1270	1.1315	1.1294	1.1335	1.1314	1.1355	1.1335	1.1376
1.1875–20	20UN	1.1330	83.9	1.1412	71.3	1.1330	1.1373	1.1352	1.1392	1.1372	1.1412	1.1391	1.1431
1.1875–28	28UN	1.1490	83.0	1.1551	69.8	1.1490	1.1520	1.1495	1.1535	1.1511	1.1551	1.1527	1.1567
1.250–7	UNC	1.0950	83.5	1.1125	74.1	1.0950	1.1040	1.0997	1.1083	1.1039	1.1125	1.1082	1.1168
1.250–8	8UN	1.1150	83.1	1.1297	74.1	1.1150	1.1222	1.1184	1.1259	1.1222	1.1297	1.1260	1.1335
1.250–12	UNF	1.1600	83.1	1.1698	74.1	1.1600	1.1648	1.1623	1.1673	1.1648	1.1698	1.1673	1.1723
1.250–16	16UN	1.1820	83.8	1.1908	72.9	1.1820	1.1866	1.1844	1.1887	1.1865	1.1908	1.1886	1.1929
1.250–18	UNEF	1.1900	83.1	1.1980	72.1	1.1900	1.1940	1.1919	1.1960	1.1939	1.1980	1.1960	1.2001
1.250–20	20UN	1.1960	83.1	1.2037	71.3	1.1960	1.1998	1.1977	1.2017	1.1997	1.2037	1.2016	1.2056
1.250–28	28UN	1.2110	84.1	1.2176	69.8	1.2110	1.2145	1.2120	1.2160	1.2136	1.2176	1.2152	1.2192
1.3125–8	8UN	1.1770	83.4	1.1922	74.1	1.1770	1.1847	1.1809	1.1884	1.1847	1.1922	1.1885	1.1960
1.3125–12	12UN	1.2220	83.6	1.2323	74.1	1.2220	1.2273	1.2248	1.2298	1.2273	1.2323	1.2298	1.2348
1.3125–16	16UN	1.2450	83.1	1.2533	72.9	1.2450	1.2491	1.2469	1.2512	1.2490	1.2533	1.2511	1.2554
1.3125–18	UNEF	1.2520	83.8	1.2605	72.1	1.2520	1.2565	1.2544	1.2585	1.2564	1.2605	1.2585	1.2626
1.3125–20	20UN	1.2580	83.9	1.2662	71.3	1.2580	1.2623	1.2602	1.2642	1.2622	1.2662	1.2641	1.2681
1.3125–28	28UN	1.2740	83.0	1.2801	69.8	1.2740	1.2770	1.2745	1.2785	1.2761	1.2801	1.2777	1.2817
1.375–6	UNC	1.1950	83.1	1.2146	74.1	1.1950	1.2046	1.1996	1.2096	1.2046	1.2146	1.2096	1.2196
1.375–8	8UN	1.2400	83.1	1.2547	74.1	1.2400	1.2472	1.2434	1.2509	1.2472	1.2547	1.2510	1.2585
1.375–12	UNF	1.2850	83.1	1.2948	74.1	1.2850	1.2898	1.2873	1.2923	1.2898	1.2948	1.2923	1.2973
1.375–16	16UN	1.3070	83.8	1.3158	72.9	1.3070	1.3116	1.3094	1.3137	1.3115	1.3158	1.3136	1.3179
1.375–18	UNEF	1.3150	83.1	1.3230	72.1	1.3150	1.3190	1.3169	1.3210	1.3189	1.3230	1.3210	1.3251
1.375–20	20UN	1.3210	83.1	1.3287	71.3	1.3210	1.3248	1.3227	1.3267	1.3247	1.3287	1.3266	1.3306
1.375–28	28UN	1.3360	84.1	1.3426	69.8	1.3360	1.3395	1.3370	1.3410	1.3386	1.3426	1.3402	1.3442
1.4375–6	6UN	1.2570	83.4	1.2771	74.1	1.2570	1.2671	1.2621	1.2721	1.2671	1.2771	1.2721	1.2821
1.4375–8	8UN	1.3020	83.4	1.3172	74.1	1.3020	1.3097	1.3059	1.3134	1.3097	1.3172	1.3135	1.3210
1.4375–12	12UN	1.3470	83.6	1.3573	74.1	1.3470	1.3523	1.3498	1.3548	1.3523	1.3573	1.3548	1.3598
1.4375–16	16UN	1.3700	83.1	1.3783	72.9	1.3700	1.3741	1.3719	1.3762	1.3740	1.3783	1.3761	1.3804
1.4375–18	UNEF	1.3770	83.8	1.3855	72.1	1.3770	1.3815	1.3794	1.3835	1.3814	1.3855	1.3835	1.3876
1.4375–20	20UN	1.3830	83.9	1.3912	71.3	1.3830	1.3873	1.3852	1.3892	1.3872	1.3912	1.3891	1.3931
1.4375–28	28UN	1.3990	83.0	1.4051	69.8	1.3990	1.4020	1.3995	1.4035	1.4011	1.4051	1.4027	1.4067
1.500–6	UNC	1.3200	83.1	1.3396	74.1	1.3200	1.3296	1.3246	1.3346	1.3296	1.3396	1.3346	1.3446
1.500–8	8UN	1.3650	83.1	1.3797	74.1	1.3650	1.3722	1.3684	1.3759	1.3722	1.3797	1.3760	1.3835
1.500–12	UNF	1.4100	83.1	1.4198	74.1	1.4100	1.4148	1.4123	1.4173	1.4148	1.4198	1.4173	1.4223
1.500–16	16UN	1.4320	83.8	1.4408	72.9	1.4320	1.4366	1.4344	1.4387	1.4365	1.4408	1.4386	1.4429
1.500–18	UNEF	1.4400	83.1	1.4480	72.1	1.4400	1.4440	1.4419	1.4460	1.4439	1.4480	1.4460	1.4501
1.500–20	20UN	1.4460	83.1	1.4537	71.3	1.4460	1.4498	1.4477	1.4517	1.4497	1.4537	1.4516	1.4556
1.500–28	28UN	1.4610	84.1	1.4676	69.8	1.4610	1.4645	1.4620	1.4660	1.4636	1.4676	1.4652	1.4692

1.5625-6	6UN	1.3820	83.4	1.4021	74.1	1.3820	1.3921	1.3871	1.3971	1.3921	1.4021	1.3971	1.4071
1.5625-8	8UN	1.4270	83.4	1.4422	74.1	1.4270	1.4347	1.4309	1.4384	1.4347	1.4422	1.4385	1.4460
1.5625-12	12UN	1.4720	83.6	1.4823	74.1	1.4720	1.4773	1.4748	1.4798	1.4773	1.4823	1.4798	1.4848
1.5625-16	16UN	1.4950	83.1	1.5033	72.9	1.4950	1.4991	1.4969	1.5012	1.4990	1.5033	1.5011	1.5054
1.5625-18	UNEF	1.5020	83.8	1.5105	72.1	1.5020	1.5065	1.5044	1.5085	1.5064	1.5105	1.5085	1.5126
1.5625-20	20UN	1.5080	83.9	1.5162	71.3	1.5080	1.5123	1.5102	1.5142	1.5122	1.5162	1.5141	1.5181
1.625-6	6UN	1.4450	83.1	1.4646	74.1	1.4450	1.4546	1.4496	1.4596	1.4546	1.4646	1.4596	1.4696
1.625-8	8UN	1.4900	83.1	1.5047	74.1	1.4900	1.4972	1.4934	1.5009	1.4972	1.5047	1.5010	1.5085
1.625-12	12UN	1.5350	83.1	1.5448	74.1	1.5350	1.5398	1.5373	1.5423	1.5398	1.5448	1.5423	1.5473
1.625-16	16UN	1.5570	83.8	1.5658	72.9	1.5570	1.5616	1.5594	1.5637	1.5615	1.5658	1.5636	1.5679
1.625-18	UNEF	1.5650	83.1	1.5730	72.1	1.5650	1.5690	1.5669	1.5710	1.5689	1.5730	1.5710	1.5751
1.625-20	20UN	1.5710	83.1	1.5787	71.3	1.5710	1.5748	1.5727	1.5767	1.5747	1.5787	1.5766	1.5806
1.6875-6	6UN	1.5070	83.4	1.5271	74.1	1.5070	1.5171	1.5121	1.5221	1.5171	1.5271	1.5221	1.5321
1.6875-8	8UN	1.5520	83.4	1.5672	74.1	1.5520	1.5597	1.5559	1.5634	1.5597	1.5672	1.5635	1.5710
1.6875-12	12UN	1.5970	83.6	1.6073	74.1	1.5970	1.6023	1.5998	1.6048	1.6023	1.6073	1.6048	1.6098
1.6875-16	16UN	1.6200	83.1	1.6283	72.9	1.6200	1.6241	1.6219	1.6262	1.6240	1.6283	1.6261	1.6304
1.6875-18	UNEF	1.6270	83.8	1.6355	72.1	1.6270	1.6315	1.6294	1.6335	1.6314	1.6355	1.6335	1.6376
1.6875-20	20UN	1.6330	83.9	1.6412	71.3	1.6330	1.6373	1.6352	1.6392	1.6372	1.6412	1.6391	1.6431
1.750-5	UNC	1.5340	83.1	1.5575	74.1	1.5340	1.5455	1.5395	1.5515	1.5455	1.5575	1.5515	1.5635
1.750-6	6UN	1.5700	83.1	1.5896	74.1	1.5700	1.5796	1.5746	1.5846	1.5796	1.5896	1.5846	1.5946
1.750-8	8UN	1.6150	83.1	1.6297	74.1	1.6150	1.6222	1.6184	1.6259	1.6222	1.6297	1.6260	1.6335
1.750-12	12UN	1.6600	83.1	1.6698	74.1	1.6600	1.6648	1.6623	1.6673	1.6648	1.6698	1.6673	1.6723
1.750-16	16UN	1.6820	83.8	1.6908	72.9	1.6820	1.6866	1.6844	1.6887	1.6865	1.6908	1.6886	1.6929
1.750-20	20UN	1.6960	83.1	1.7037	71.3	1.6960	1.6998	1.6977	1.7017	1.6997	1.7037	1.7016	1.7056
1.8125-6	6UN	1.6320	83.4	1.6521	74.1	1.6320	1.6421	1.6371	1.6471	1.6421	1.6521	1.6471	1.6571
1.8125-8	8UN	1.6770	83.4	1.6922	74.1	1.6770	1.6847	1.6809	1.6884	1.6847	1.6922	1.6885	1.6960
1.8126-12	12UN	1.7220	83.6	1.7323	74.1	1.7220	1.7273	1.7248	1.7298	1.7273	1.7323	1.7298	1.7348
1.8125-16	16UN	1.7450	83.1	1.7533	72.9	1.7450	1.7491	1.7469	1.7512	1.7490	1.7533	1.7511	1.7554
1.8125-20	20UN	1.7580	83.9	1.7662	71.3	1.7580	1.7623	1.7602	1.7642	1.7622	1.7662	1.7641	1.7681
1.875-6	6UN	1.6950	83.1	1.7146	74.1	1.6950	1.7046	1.6996	1.7096	1.7046	1.7146	1.7096	1.7196
1.875-8	8UN	1.7400	83.1	1.7547	74.1	1.7400	1.7472	1.7434	1.7509	1.7472	1.7547	1.7510	1.7585
1.875-12	12UN	1.7850	83.1	1.7948	74.1	1.7850	1.7898	1.7873	1.7923	1.7898	1.7948	1.7923	1.7973
1.875-16	16UN	1.8070	83.8	1.8158	72.9	1.8070	1.8116	1.8094	1.8137	1.8115	1.8158	1.8136	1.8179
1.875-20	20UN	1.8210	83.1	1.8287	71.3	1.8210	1.8248	1.8227	1.8267	1.8247	1.8287	1.8266	1.8306
1.9375-6	6UN	1.7570	83.4	1.7771	74.1	1.7570	1.7671	1.7621	1.7721	1.7671	1.7771	1.7721	1.7821
1.9375-8	8UN	1.8020	83.4	1.8172	74.1	1.8020	1.8097	1.8059	1.8134	1.8097	1.8172	1.8135	1.8210
1.9375-12	12UN	1.8470	83.6	1.8573	74.1	1.8470	1.8523	1.8498	1.8548	1.8523	1.8573	1.8548	1.8598
1.9375-16	16UN	1.8700	83.1	1.8783	72.9	1.8700	1.8741	1.8719	1.8762	1.8740	1.8783	1.8761	1.8804
1.9375-20	20UN	1.8830	83.9	1.8912	71.3	1.8830	1.8873	1.8852	1.8892	1.8872	1.8912	1.8891	1.8931
2.000-4.5	UNC	1.7590	83.5	1.7861	74.1	1.7590	1.7727	1.7661	1.7794	1.7728	1.7861	1.7794	1.7927
2.000-6	6UN	1.8200	83.1	1.8396	74.1	1.8200	1.8296	1.8246	1.8346	1.8296	1.8396	1.8346	1.8446
2.000-8	8UN	1.8650	83.1	1.8797	74.1	1.8650	1.8722	1.8684	1.8759	1.8722	1.8797	1.8760	1.8835
2.000-12	12UN	1.9100	83.1	1.9198	74.1	1.9100	1.9148	1.9123	1.9173	1.9148	1.9198	1.9173	1.9223
2.000-16	16UN	1.9320	83.8	1.9408	72.9	1.9320	1.9366	1.9344	1.9387	1.9365	1.9408	1.9386	1.9429
2.000-20	20UN	1.9460	83.1	1.9537	71.3	1.9460	1.9498	1.9477	1.9517	1.9497	1.9537	1.9516	1.9556
2.0625-16	UNS	1.9950	83.1	2.0033	72.9	1.9950	1.9991	1.9969	2.0012	1.9990	2.0033	2.0011	2.0054
2.125-6	6UN	1.9450	83.1	1.9646	74.1	1.9450	1.9546	1.9496	1.9596	1.9546	1.9646	1.9596	1.9696
2.125-8	8UN	1.9900	83.1	2.0047	74.1	1.9900	1.9972	1.9934	2.0009	1.9972	2.0047	2.0010	2.0085
2.125-12	12UN	2.0350	83.1	2.0448	74.1	2.0350	2.0398	2.0373	2.0423	2.0398	2.0448	2.0423	2.0473
2.125-16	16UN	2.0570	83.8	2.0658	72.9	2.0570	2.0616	2.0594	2.0637	2.0615	2.0658	2.0636	2.0679
2.125-20	20UN	2.0710	83.1	2.0787	71.3	2.0710	2.0748	2.0727	2.0767	2.0747	2.0787	2.0766	2.0806
2.1875-16	UNS	2.1200	83.1	2.1283	72.9	2.1200	2.1241	2.1219	2.1262	2.1240	2.1283	2.1261	2.1304
2.250-4.5	UNC	2.0090	83.5	2.0361	74.1	2.0090	2.0227	2.0161	2.0294	2.0228	2.0361	2.0294	2.0427
2.250-6	6UN	2.0700	83.1	2.0896	74.1	2.0700	2.0796	2.0746	2.0846	2.0796	2.0896	2.0846	2.0946
2.500-4	UNC	2.2290	83.4	2.2594	74.1	2.2290	2.2444	2.2369	2.2519	2.2444	2.2594	2.2519	2.2669
2.750-4	UNC	2.4790	83.4	2.5094	74.1	2.4790	2.4944	2.4869	2.5019	2.4944	2.5094	2.5019	2.5169
3.000-4	UNC	2.7290	83.4	2.7594	74.1	2.7290	2.7444	2.7369	2.7519	2.7444	2.7594	2.7519	2.7669
3.250-4	UNC	2.9790	83.4	3.0094	74.1	2.9790	2.9944	2.9869	3.0019	2.9944	3.0094	3.0019	3.0169

[a] The differences between limits are equal to the minor diameter tolerances given in table 3.10 for lengths of engagement to and including $0.33D$. However, the minimum values for lengths of engagement greater than $0.33D$ in sizes 0.25 in. and larger are adjusted so that the difference between limits is never less than 0.0040 in. For diameter-pitch combinations other than those given in this table, the tolerances given in table 3.10 should be similarly applied to determine hole size limits.

Hole size limits for diameter-pitch combinations which do not appear in this table may be obtained by use of values in this table provided there is a diameter-pitch combination in the table:

(1) with the same pitch and

(2) with a diameter that is less by an integral amount than the diameter of the diameter-pitch combination for which hole size values are desired. (NOTE: Values in the table for nominal sizes less than 1.00 in. cannot be used for this purpose.)

EXAMPLE: To obtain the values for the 4.000-8UN-3B thread, add 2.000 to the values for the 2.000-8UN thread shown in the table. These values would then become: 3.8650, 3.8722, 3.8684, 3.8759, 3.8722, 3.8797, 3.8760, 3.8835. The percentages of basic thread height will remain unchanged.

[b] Based on values as rounded off in the preceding column. 100 percent basic thread height = $0.75H$ (values of $0.75H$ are shown in col. 14, table 2.1).

[c] Based on a length of engagement equal to the nominal diameter.

TABLE A3.7. *Recommended hole size limits before threading for different lengths of engagement, Unified National Miniature, UNM, thread series*

Thread designation			Minor diameter of internal threads				Recommended hole size limits for different lengths of engagement [a]					
							To and including 0.67*D*		Above 0.67*D* to 1.5*D*		Above 1.5*D* to 3*D*	
Preferred	Secondary		Min	Percent basic thread height	Max	Percent basic thread height	Min	Max	Min	Max	Min	Max
		Pitch *mm*	*mm*		*mm*		*mm*	*mm*	*mm*	*mm*	*mm*	*mm*
.30UNM		0.080	0.223	100	0.260	51.9	0.232	0.246	0.241	0.260	0.251	0.269
	.35UNM	.090	.264	100	.305	52.3	.274	.290	.284	.305	.295	.315
.40UNM		.100	.304	100	.348	54.2	.315	.332	.326	.348	.337	.359
	.45UNM	.100	.354	100	.398	54.2	.365	.382	.376	.398	.387	.409
.50UNM		.125	.380	100	.432	56.7	.393	.412	.406	.432	.419	.445
	.55UNM	.125	.430	100	.482	56.7	.443	.462	.456	.482	.469	.495
.60UNM		.150	.456	100	.516	58.3	.471	.494	.486	.516	.501	.531
	.70UNM	.175	.532	100	.600	59.5	.549	.574	.566	.600	.583	.617
.80UNM		.200	.608	100	.684	60.4	.627	.656	.646	.684	.665	.703
	.90UNM	.225	.684	100	.768	61.1	.705	.736	.726	.768	.747	.789
1.00UNM		.250	.760	100	.852	61.7	.783	.818	.806	.852	.829	.875
	1.10UNM	.250	.860	100	.952	61.7	.883	.918	.906	.952	.929	.975
1.20UNM		.250	.960	100	1.052	61.7	.983	1.018	1.006	1.052	1.029	1.075
	1.40UNM	.300	1.112	100	1.220	62.5	1.139	1.180	1.166	1.220	1.193	1.247
		Thds per inch	*in*		*in*		*in*	*in*	*in*	*in*	*in*	*in*
.30UNM		318	0.0088	100	0.0102	51.9	0.0092	0.0097	0.0095	0.0102	0.0098	0.0106
	.35UNM	282	.0104	100	.0120	52.3	.0108	.0114	.0112	.0120	.0116	.0124
.40UNM		254	.0120	100	.0137	54.2	.0124	.0131	.0128	.0137	.0133	.0141
	.45UNM	254	.0139	100	.0157	54.2	.0143	.0150	.0148	.0157	.0153	.0161
.50UNM		203	.0150	100	.0170	56.7	.0155	.0162	.0160	.0170	.0165	.0175
	.55UNM	203	.0169	100	.0190	56.7	.0174	.0182	.0179	.0190	.0185	.0195
.60UNM		169	.0180	100	.0203	58.3	.0186	.0194	.0192	.0203	.0197	.0209
	.70UNM	145	.0209	100	.0236	59.5	.0216	.0226	.0223	.0236	.0229	.0243
.80UNM		127	.0239	100	.0269	60.4	.0247	.0258	.0254	.0269	.0261	.0277
	.90UNM	113	.0269	100	.0302	61.1	.0277	.0290	.0285	.0302	.0294	.0310
1.00UNM		102	.0299	100	.0335	61.7	.0308	.0321	.0317	.0335	.0326	.0344
	1.10UNM	102	.0339	100	.0375	61.7	.0348	.0361	.0357	.0375	.0366	.0384
1.20UNM		102	.0378	100	.0414	61.7	.0387	.0400	.0396	.0414	.0405	.0423
	1.40UNM	85	.0438	100	.0480	62.5	.0448	.0464	.0459	.0480	.0470	.0490

[a] Limited experience indicates these sizes to be suitable for easily machineable materials (brass, nickel-silver, etc.). For materials more difficult to machine, hole size limits in the next larger category are suggested. In instances where hole sizes in excess of the maximum minor diameter are necessary, the excess is usually recovered in the thread form by the spin-up resulting from the negative rake with which these small taps must be ground.

UNITED STATES DEPARTMENT OF COMMERCE

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SCREW-THREAD STANDARDS

FOR FEDERAL SERVICES

APPENDIX A4

1969

METHODS OF WIRE MEASUREMENT OF PITCH DIAMETER OF 60° THREADS

On a straight thread, the pitch diameter is the diameter of the cylinder whose surface passes through the thread profiles at such points as to make the widths of thread groove and thread ridge equal.

On a taper thread, the pitch diameter at a given position on the thread axis is the diameter of the pitch cone at that position.

The degree of accuracy to which the pitch diameter can be measured will depend on the accuracy of lead, helix, and form of thread. As thread plug gages and thread setting plug gages have highly accurate threads, their pitch diameters may be measured to a correspondingly high degree of accuracy by applying the methods described in this appendix. In turn, the *virtual diameters* (*or effective sizes*) of thread ring, most snap, and most indicating gages may be determined by fitting or comparison with such setting plug gages. Those snap and indicating gages which utilize elements with curved contacts have a pitch (simple effective) diameter determined by comparison to the applicable setting plug gages.

As most threads of mechanical fasteners and components are made to a lesser degree of accuracy than gage threads, their pitch diameters are not susceptible to accurate determination by direct measuring methods. Therefore, it is not recommended that such threads be measured by the use of wires. On such threads, the pitch diameter is to be regarded as the pitch cylinder or cone which would bound, on the maximum-material side, the approximately cylindrical or conical surface which would pass through the thread profiles at all points such that the widths of the thread and groove are equal. Accordingly, the conformity of such threads with specified pitch diameter limits is determined by gaging means and methods specified in section 6.

The accurate measurement of pitch diameter of a thread, which may be perfect as to form and lead, presents certain difficulties which result in some uncertainty as to its true value. The adoption of a standard uniform practice in making such measurements is, therefore, desirable in order to reduce such uncertainty of measurement to a minimum. The so-called "three-wire method" of measuring pitch diameter of straight thread plug gages, as outlined herein, has been found to be the most generally satisfactory method when properly carried out, and is recommended for universal use in the direct measurement of thread plug and thread setting plug gages. (See fig. A4.1.)

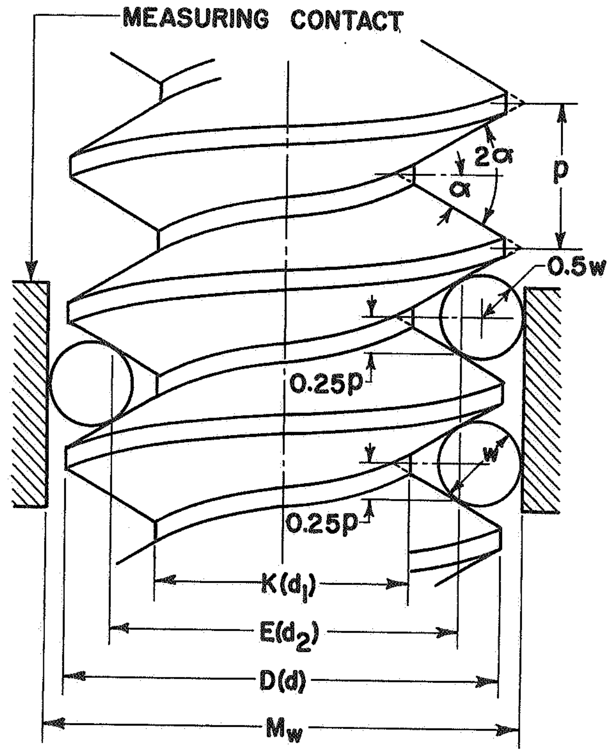

FIGURE A4.1. *Three-wire method of measuring pitch diameter of straight thread plug gages.*

1. SIZE OF WIRES

In the three-wire method of measuring pitch diameter, small hardened steel cylinders or wires of correct size are placed in the thread groove, two on one side of the screw and one on the opposite side, as shown in figure A4.1. The contact face of the comparator, measuring machine, or micrometer anvil or spindle over the two wires must be sufficiently large in diameter to touch both wires; that is, the diameter must be greater than the pitch of the thread. It is best to select wires of such size that they touch the flanks of the thread at the midslope since the measurement of pitch diameter is least affected by any deviation in thread angle that may be present when such size is used. The size of wire that touches exactly at the midslope of a perfect thread of a given pitch is termed the "best-size" wire for that pitch. Any size, however, may be used that will permit the wires to rest on the flanks of the thread and also project above the crest of the thread.

The depth at which a wire of given diameter will rest in a thread groove depends primarily on the pitch and included angle of the thread and, secondarily, on the angle made by the helix at the point of contact of the wire and the thread, with a plane perpendicular to the axis of the screw. Inasmuch as variation in the lead angle has a very small effect in determining the diameter of the wire that touches at the midslope of the thread, and as it is desirable to use one size of wire to measure all threads of a given pitch and included angle, the best-size wire is taken as that size which will touch at the midslope of a groove cut around a cylinder perpendicular to the axis of the cylinder, and of the same angle and depth as the thread of the given pitch. This is equivalent to a thread of zero lead angle. The size of wire touching at the midslope, or "best-size" wire, is given by the formula:

$$W=\frac{p}{2}\sec\alpha$$

in which

W = diameter of wire

p = pitch

α = half included angle of thread.

This formula reduces to—

$$W=0.57735p, \text{ for } 60^\circ \text{ threads.}$$

TABLE A4.2. *Wire sizes and constants for all USA Standard 60° threads (Unified, hose-coupling, and pipe)*

Threads per inch, n	Pitch, $p=\frac{1}{n}$	Pitch $\frac{p}{2}$, $\frac{p}{2}=\frac{1}{2n}$	Depth of V thread, $\frac{\cot 30^\circ}{2n}$	Wire sizes[a] Best, $0.577350p$	Maximum, $1.010363p$	Minimum, $0.505182p$
1	2	3	4	5	6	7
	in	*in*	*in*	*in*	*in*	*in*
80	0.012500	0.00625	0.010825	0.00722	0.01263	0.00631
72	.013889	.00694	.012028	.00802	.01403	.00702
64	.015625	.00781	.013532	.00902	.01579	.00789
56	.017857	.00893	.015465	.01031	.01804	.00902
50	.020000	.01000	.017321	.01155	.02021	.01010
48	.020833	.01042	.018042	.01203	.02105	.01052
44	.022727	.01136	.019682	.01312	.02296	.01148
40	.025000	.01250	.021651	.01443	.02526	.01263
36	.027778	.01389	.024056	.01604	.02807	.01403
32	.031250	.01562	.027063	.01804	.03157	.01579
30	.033333	.01667	.028868	.01925	.03368	.01684
28	.035714	.01786	.030929	.02062	.03608	.01804
27	.037037	.01852	.032075	.02138	.03742	.01871
26	.038462	.01923	.033309	.02221	.03886	.01943
24	.041667	.02083	.036084	.02406	.04210	.02105
22	.045445	.02273	.039365	.02624	.04592	.02296
20	.050000	.02500	.043301	.02887	.05052	.02526
18	.055556	.02778	.048113	.03208	.05613	.02807
16	.062500	.03125	.054127	.03608	.06315	.03157
14	.071429	.03571	.061859	.04124	.07217	.03608
13	.076923	.03846	.066617	.04441	.07772	.03886
12	.083333	.04167	.072169	.04811	.08420	.04210
11.5	.086957	.04348	.075307	.05020	.08786	.04393
11	.090909	.04545	.078730	.05249	.09185	.04593
10	.100000	.05000	.086603	.05774	.10104	.05052
9	.111111	.05556	.096225	.06415	.11226	.05613
8	.125000	.06250	.108253	.07217	.12630	.06315
7.5	.133333	.06667	.115470	.07698	.13472	.06736
7	.142857	.07143	.123718	.08248	.14434	.07217
6	.166667	.08333	.144338	.09623	.16839	.08420
5.5	.181818	.09091	.157459	.10497	.18370	.09185
5	.200000	.10000	.173205	.11547	.20207	.10104
4.5	.222222	.11111	.192450	.12830	.22453	.11226
4	.250000	.12500	.216506	.14434	.25259	.12630

[a] These wire sizes are based on zero lead angle. Also maximum and minimum sizes are based on a width of flat at the crest equal to 0.125p. The width of flat of USA Standard pipe thread gages is slightly less than this, so that the minimum size listed is slightly too small for such gages. In any case the use of wires of either extreme size is to be avoided.

It is frequently desirable, as, for example, when a best-size wire is not available, to measure pitch diameter by means of wires of other than the best size. The minimum size that may be used is limited to that permitting the wire to project above the crest of the thread, and the maximum to that permitting the wire to rest on the flanks of the thread just below the crest, and not ride on the crest of the thread. The diameters of the best size, maximum, and minimum wires for all USA Standard 60° threads are given in tables A4.2 and A4.3.

When using wires of other than the best-size, precautions must be observed in the calculation of pitch diameter. Actual measured values for half-angles and the angle between the axis of the wire and a plane perpendicular to the axis of the thread must be used for the calculation of pitch diameter when using wires other than best-size. The uncertainties of the values used and the different wire contact conditions will increase the uncertainty of the pitch diameter measurement.

2. METHODS OF MEASURING AND USING WIRES

The computed value for the pitch diameter of a screw thread gage obtained from readings over wires will depend upon the accuracy of the measuring instrument used, the contact force, and the value of the diameter of the wires used in the computations. In order to measure the pitch diameter of a 60° screw-thread gage to an accuracy within 0.0001 in by means of wires, it is necessary to know the wire diameters to within 0.00002 in. Accordingly, it is necessary to use a measuring instrument that reads accurately to 0.00001 in.

Variations in diameter around the wire should be determined by rotating the wire between a flat measuring contact and an anvil having the form of a 60° V-groove. Variations in diameter along the wire should be determined by measuring between a flat contact and a cylindrical anvil.

A wire presses on the flanks of a 60° thread with the force that is applied to the wire by the measuring instrument. Inasmuch as the wire and thread deform at the contact areas, it is desirable to determine the size of the wire under conditions which will compensate for this deformation. It is recommended for standard practice that diameters of wires be measured between a flat contact and a hardened and accurately ground and lapped steel cylinder having a diameter of 0.125 in. for wires used on threads having more than 40 up to and including 80 tpi and 0.750 in. for wires used on threads having 40 and fewer tpi with the force used in measuring the pitch diameter of the gage. The plane of the

Table A4.3. *Relation of best wire diameters to pitches for all USA Standard 60° threads (Unified, hose-coupling, and pipe)*[a]

Best wire sizes (in inches)	Threads per inch (tpi)																																	
	80	72	64	56	50	48	44	40	36	32	30	28	27	26	24	22	20	18	16	14	13	12	11.5	11	10	9	8	7.5	7	6	5.5	5	4.5	4
0.00722	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.00802	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.00902	X	X	⊗	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.01031	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.01155	X	X	X	X	⊗	X	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.01203	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.01312	---	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.01443	---	---	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.01604	---	---	---	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.01804	---	---	---	---	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.01925	---	---	---	---	X	X	X	X	X	X	⊗	X	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.02062	---	---	---	---	---	X	X	X	X	X	X	⊗	X	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.02138	---	---	---	---	---	---	X	X	X	X	X	X	⊗	X	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.02221	---	---	---	---	---	---	X	X	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.02406	---	---	---	---	---	---	---	X	X	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.02624	---	---	---	---	---	---	---	---	X	X	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.02887	---	---	---	---	---	---	---	---	---	X	X	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.03208	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.03608	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	X	⊗	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
.04124	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---	---	---	---
.04441	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	⊗	X	X	---	---	---	---	---	---	---	---	---	---	---
.04811	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	⊗	X	X	---	---	---	---	---	---	---	---	---	---
.05020	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---	---
.05249	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---	---
.05774	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---	---
.06415	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	X	⊗	X	---	---	---	---	---	---	---
.07217	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	X	⊗	X	---	---	---	---	---	---
.07698	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	X	X	⊗	X	---	---	---	---	---
.08248	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	X	X	⊗	---	---	---	---	---
.09623	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	⊗	X	---	---	---
.10497	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	⊗	X	---	---
.11547	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	⊗	X	---
.12830	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	X	⊗	X
.14434	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X	X	X	X	⊗

[a] The crosses (X) indicate those wire diameters which can be used for each pitch. An encircled cross (⊗) indicates the "best wire" diameter for that tpi which heads the column.

flat contact should be parallel to the contact element of the cylinder within 0.000005 in.

To avoid a permanent deformation of the material of the wires or gages, it is necessary to limit the contact force and, for consistent results, a uniform practice as to contact force in making wire measurements of hardened screw threads gages is necessary. The practice recommended is to use the following forces:

Threads per inch	Measuring force (±10%)
20 or less	2.5 pounds
Above 20 thru 40	1 pound
Above 40 thru 80	8 ounces
Above 80 thru 140	4 ounces
Above 140	2 ounces

The use of other contact forces will cause a difference in the reading over the wires and to completely compensate for such errors is impractical.

The practice of using holding means, such as rubber bands, which has a tendency to prevent the wires from adjusting themselves to the proper position in the thread grooves, will result in false measurements. In some cases it has also been the practice to support the gage being measured on two wires, which are in turn supported on a horizontal surface, and measuring from this surface to the top of a wire placed over and between the other wires. If the gage is of large diameter, its weight causes an increase in the elastic deformation at the contact points and an inaccurate reading is obtained. Tests on a 1–12 UNF setting plug gage showed a 0.00001 in. error when measured in this manner. This practice should therefore be avoided for gages of such size and larger. Wires from different sets of the same nominal diameter should not be mixed unless calibrated because thread wires in different sets may not have the same diameter. (See par. 3.2.)

In order to minimize the deviation of the measured pitch diameter from the true pitch diameter (neglecting the effect of lead angle) and reduce the chance of permanently deforming the gages and wires, this revision contains a change in the recommended measuring practice for threads and wires for threads having more than 40 up to and including 80 tpi. The new recommended practice reduces the force for measuring gages and wires from one to 0.5 lb and the size of the cylinder over which the wires are measured from 0.750 to 0.125 in. As a result of this change, the measured pitch diameters of threads in this range will be approximately 0.00005 in. larger than they were under the previous recommended practice.

The measured value will be much closer to the true pitch diameter, however. *Plug gages manu-*

factured prior to this revision and within tolerance when measured under the previous recommended practice but not within tolerance when measured under the new recommended practice should be considered as within tolerance for a transition period. With the new recommended practice, it can be shown that for all sizes of threads up to 1.500 in. in the fine thread series (UNF) and all sizes up to 2.000 in. in the coarse thread series (UNC), the measured pitch diameter will not differ from the true pitch diameter (neglecting the effect of lead angle) in excess of 0.000035 in. Slightly larger discrepancies in the 2 to 4 in. size range are relatively unimportant because these sizes have larger tolerances. The measured diameter of the thread wires for threads having more than 40 up to and including 80 tpi under the new recommended practice differ by less than two microinches from the measured diameter under the previous recommended practice. Therefore, neither wire diameters nor corrections for computing pitch diameter need be changed.

Measurements of a thread plug gage made in accordance with these instructions, with wires that conform to the following specifications, should be accurate to within 0.0001 in.

3. STANDARD SPECIFICATION FOR WIRES AND STANDARD PRACTICE IN MEASUREMENT OF WIRES

The following specifications represent present practice relative to thread measuring wires:

3.1. COMPOSITION.—The wires shall be accurately finished, hardened steel cylinders of the maximum possible hardness without being brittle. The hardness shall not be less than that corresponding to a Knoop indentation number of 630. A wire of this hardness can be cut with a file only with difficulty. The surface shall not be rougher than the equivalent of one having a surface roughness rating of 2 microinches arithmetical average.

3.2. DIAMETER OF WIRES.—One set of wires shall consist of three wires that shall have the same diameter within 0.00001 in., and this common diameter shall be within 0.00002 in of that corresponding to the best size for the tpi for which the wire is to be used. Wires shall be measured between a flat contact and a hardened and accurately finished cylinder having a surface roughness rating not in excess of 2 microinches arithmetical average. The measuring forces and cylinder diameters shall be as follows:

Threads per inch	Measuring force (±10%)	Cylinder diameter
20 or less	2.5 pounds	0.750 inch
Above 20 thru 40	1 pound	0.750 inch
Above 40 thru 80	8 ounces	0.125 inch
Above 80 thru 140	4 ounces	0.050 inch
Above 140	2 ounces	0.020 inch

Using these conditions, the uncertainties of the wire diameter measurement due to other metrological considerations should be limited and not exceed 0.000010 in.

An acceptable technique for the measurement of the diameter of each set of thread measuring wires is to compare them to a reference master wire with a suitable comparison measuring instrument having any anvil shape or measuring force consistent with good metrological practice. The diameter of each reference master wire, however, must be calibrated by the specified technique with an uncertainty not in excess of 0.000005 in.

Wires which are to be used where the contact of the wire is a line contact, such as in gear wires, should not be used for measuring thread gages. The recommended practice for measuring such wires is between flat parallel contacts with a one pound force.

3.3. VARIATIONS IN DIAMETER.—Variations in diameter along a wire (taper) over the 1 in. interval at the center of its length shall not exceed 0.000010 in as determined by measuring between a flat contact and a cylindrical contact. Variations from true cylindrical contour of a wire (out-of-roundness or noncircular cross section) over its 1 in. central interval shall not exceed 0.000010 in as determined by measuring between a flat measuring contact and a well finished 60° V-groove.

Tests for compliance of thread measuring wires with the above specifications are made by the National Bureau of Standards for a stated fee.

4. GENERAL FORMULA FOR MEASUREMENT OF PITCH DIAMETER

The general formula for determining the pitch diameter of any thread whose flanks are symmetrical with respect to a line drawn through the vertex and perpendicular to the axis of the thread, in which the slight effect of lead angle is taken into account, is

$$E = M_w + \frac{\cot \alpha}{2n} - w[1 + (\operatorname{cosec}^2 \alpha + \cot^2 \alpha \tan^2 \lambda')^{1/2}], \tag{1}$$

in which

E = pitch diameter
M_w = measurement over wires
α = half angle of thread
n = number of threads per inch $= 1/p$
w = mean diameter of wires
λ' = angle between axis of wire and plane perpendicular to axis of thread.

This formula is a very close approximation, being based on certain assumptions regarding the positions of the points of contact between the wire and the thread.

Formula (1) can be converted to the following simplified form, which is particularly useful when measuring threads of large lead angle:

$$E = M_w + \frac{\cot \alpha}{2n} - w(1 + \operatorname{cosec} \alpha'), \qquad (2)$$

in which α' = the angle whose tangent = $\tan \alpha \cos \lambda'$.

When formula (1) is used, the usual practice is to expand the square root term as a series, retaining only the first and second terms, which gives the following:

$$E = M_w + \frac{\cot \alpha}{2n} - w\left(1 + \operatorname{cosec} \alpha + \frac{\tan^2 \lambda' \cos \alpha \cot \alpha}{2}\right). \qquad (3)$$

For large lead angles it is necessary to measure the wire angle, λ', but for lead angles of 5° or less, if the "best-size" wire is used, this angle may be assumed to be equal to the lead angle of the thread at the pitch line, λ. The value of $\tan \lambda$, the tangent of the lead angle, is given by the formula

$$\tan \lambda = \frac{L}{3.1416E} = \frac{1}{3.1416NE}$$

in which

L = lead

N = number of turns per inch

E = nominal pitch diameter, or an approximation of the measured pitch diameter.

5. MEASUREMENT OF PITCH DIAMETER OF ALL USA STANDARD 60° STRAIGHT THREADS (UNIFIED, HOSE-COUPLING, AND PIPE)

For threads of the Unified standard series, the term

$$\frac{w \tan^2 \lambda' \cos \alpha \cot \alpha}{2}$$

is neglected, as its value is small, being in all cases less than 0.00015 in for standard fastening screws when the best-size wire is used, and the above formula (3) takes the simplified form

$$E = M_w + \frac{\cot \alpha}{2n} - w(1 + \operatorname{cosec} \alpha). \qquad (4)$$

This practice is permissible provided that it is uniformly followed, and in order to maintain uniformity of practice, and thus avoid confusion, the National Bureau of Standards uses formula (4) for such threads. The Bureau also uses formula (4) for special 60° threads, except when the value of the term

$$\frac{w \tan^2 \lambda' \cos \alpha \cot \alpha}{2}$$

exceeds 0.00015 in., as in the case of multiple threads, or other threads having exceptionally large lead angles. For 60° threads this term exceeds 0.00015 when $NE\sqrt{n}$ is less than 17.1.

For a 60° thread of correct angle and thread form formula (4) simplifies to

$$E = M_w + \frac{0.86603}{n} - 3w. \qquad (5)$$

For a given set of best-size wires

$$E = M_w - C$$

when

$$C = w(1 + \operatorname{cosec} \alpha) - \frac{\cot \alpha}{2n}$$

The quantity C is a constant for a given thread angle, and, when the wires are used for measuring threads of the pitch and angle for which they are the best size, the pitch diameter is obtained by the simple operation of subtracting this constant from the measurement taken over the wires. In fact, when best-size wires are used, this constant is changed very little by a moderate deviation in the angle of the thread. Consequently, the constants for the various sets of wires in use may be tabulated, thus saving a considerable amount of time in the inspection of gages. However, when wires of other than the best size are used, this constant changes appreciably with a deviation in the angle of the thread.

It has been shown that, with the exception of coarse pitch screws, variation in angle from the basic size causes no appreciable change in the quantity C for the best-size wires. On the other hand, when a wire near the maximum or minimum allowable size is used, a considerable change occurs, and the values of the cotangent and cosecant of the actual measured half angle are to be used. It is apparent, therefore, that there is a great advantage in using wires very closely approximating the best size. For convenience in carrying out computations, the values of cot $\alpha/2n$ for standard pitches are given in table A4.2.

When the value of the term

$$\left(\frac{w \tan^2 \lambda' \cos \alpha \cot \alpha}{2}\right)$$

exceeds 0.00015 in., the following pitch diameter formula should be used:

$$E = M_w - (C + c)$$

Tabular values for $(C+c)_1$ for a 1-in axial pitch screw for 60° threads are given in table A4.4 which values should be divided by the threads per inch for a given case. (See appendix in Part III, titled "Three-wire method of measurement of pitch diameter of 29° Acme, 29° Stub Acme, and Buttress threads," for further details.)

TABLE A4.4. *Best wire diameters and constants for large lead angles, 1-in axial pitch 60° threads*

Lead angle, λ	1-start threads		2-start threads	
	w_1	$(C+c)_1$	w_1	$(C+c)_1$
1	2	3	4	5
deg	*in*	*in*	*in*	*in*
5.0	0.57493	0.86181	0.57477	0.86145
5.1	.57483	.86165	.57467	.86127
5.2	.57474	.86149	.57456	.86109
5.3	.57465	.86133	.57446	.86091
5.4	.57456	.86117	.57435	.86072
5.5	.57446	.86100	.57425	.86053
5.6	.57436	.86083	.57414	.86034
5.7	.57426	.86066	.57403	.86015
5.8	.57416	.86049	.57392	.85995
5.9	.57406	.86032	.57381	.85976
6.0	.57395	.86014	.57369	.85956
6.1	.57385	.85996	.57358	.85936
6.2	.57374	.85978	.57346	.85915
6.3	.57363	.85960	.57333	.85893
6.4	.57352	.85942	.57320	.85871
6.5	.57341	.85923	.57308	.85850
6.6	.57330	.85904	.57295	.85828
6.7	.57318	.85885	.57282	.85805
6.8	.57307	.85866	.57269	.85782
6.9	.57295	.85847	.57256	.85760
7.0	.57284	.85828	.57242	.85737
7.1	.57272	.85808	.57228	.85713
7.2	.57260	.85788	.57215	.85689
7.3	.57248	.85768	.57201	.85664
7.4	.57236	.85747	.57187	.85640
7.5	.57223	.85727	.57173	.85616
7.6	.57211	.85706	.57159	.85591
7.7	.57198	.85685	.57144	.85566
7.8	.57185	.85664	.57129	.85540
7.9	.57171	.85642	.57114	.85515
8.0	.57158	.85620	.57100	.85490
8.1	.57144	.85598	.57085	.85464
8.2	.57131	.85576	.57070	.85438
8.3	.57117	.85554	.57054	.85411
8.4	.57104	.85533	.57038	.85383
8.5	.57090	.85511	.57022	.85356
8.6	.57076	.85489	.57007	.85329
8.7	.57063	.85466	.56991	.85301
8.8	.57049	.85444	.56974	.85273
8.9	.57035	.85421	.56958	.85245
9.0	.57021	.85398	.56941	.85217
9.1	.57007	.85375	.56924	.85188
9.2	.56993	.85352	.56907	.85159
9.3	.56978	.85329	.56890	.85130
9.4	.56964	.85305	.56873	.85100
9.5	.56949	.85282	.56856	.85070
9.6	.56935	.85258	.56838	.85040
9.7	.56920	.85235	.56820	.85010
9.8	.56905	.85211	.56803	.84980
9.9	.56890	.85187	.56785	.84949
10.0	.56875	.85163	.56767	.84918

Lead angle, λ	2-start threads		3-start threads	
	w_1	$(C+c)_1$	w_1	$(C+c)_1$
1	4	5	6	7
deg	*in*	*in*	*in*	*in*
10.0	0.56767	0.84918	0.56728	0.84830
10.1	.56749	.84887	.56709	.84797
10.2	.56730	.84856	.56689	.84763
10.3	.56711	.84824	.56669	.84729
10.4	.56693	.84793	.56649	.84695
10.5	.56674	.84761	.56629	.84660
10.6	.56656	.84729	.56609	.84625
10.7	.56637	.84697	.56589	.84589
10.8	.56617	.84664	.56568	.84553
10.9	.56598	.84631	.56547	.84517
11.0	.56578	.84598	.56526	.84481
11.1	.56558	.84564	.56506	.84445
11.2	.56538	.84530	.56485	.84409
11.3	.56518	.84497	.56463	.84372
11.4	.56498	.84463	.56441	.84335
11.5	.56478	.84429	.56420	.84298
11.6	.56457	.84394	.56398	.84260
11.7	.56437	.84360	.56375	.84221
11.8	.56416	.84325	.56353	.84183
11.9	.56396	.84290	.56331	.84145
12.0	.56375	.84255	.56308	.84106
12.1	.56353	.84219	.56285	.84067
12.2	.56332	.84183	.56263	.84028
12.3	.56311	.84147	.56240	.83989
12.4	.56289	.84111	.56217	.83949
12.5	.56267	.84075	.56193	.83908
12.6	.56245	.84038	.56170	.83868
12.7	.56223	.84001	.56147	.83828
12.8	.56201	.83964	.56123	.83787
12.9	.56179	.83927	.56099	.83746
13.0	.56157	.83890	.56075	.83705
13.1	.56135	.83853	.56051	.83664
13.2	.56113	.83815	.56027	.83622
13.3	.56090	.83777	.56002	.83579
13.4	.56067	.83739	.55977	.83537
13.5	.56044	.83701	.55952	.83495
13.6	.56021	.83662	.55927	.83452
13.7	.55997	.83623	.55902	.83409
13.8	.55974	.83584	.55877	.83366
13.9	.55950	.83545	.55852	.83323
14.0	.55926	.83506	.55827	.83280
14.1	.55903	.83467	.55802	.83237
14.2	.55880	.83428	.55776	.83193
14.3	.55856	.83388	.55750	.83149
14.4	.55831	.83347	.55724	.83105
14.5	.55807	.83307	.55698	.83060
14.6	.55782	.83266	.55671	.83014
14.7	.55757	.83225	.55645	.82969
14.8	.55733	.83185	.55618	.82923
14.9	.55709	.83145	.55590	.82877
15.0	.55684	.83104	.55563	.82831

TABLE A4.4. *Best wire diameters and constants for large lead angles, 1-in axial pitch 60° threads*—Continued

Lead angle, λ	3-start threads		4-start threads	
	w_1	$(C+c)_1$	w_1	$(C+c)_1$
1	6	7	8	9
deg	*in*	*in*	*in*	*in*
13.0	.56075	.83705	.56033	.83609
13.1	.56051	.83664	.56008	.83566
13.2	.56027	.83622	.55982	.83522
13.3	.56002	.83579	.55956	.83477
13.4	.55977	.83537	.55931	.83433
13.5	.55952	.83495	.55905	.83388
13.6	.55927	.83452	.55879	.83342
13.7	.55902	.83409	.55853	.83297
13.8	.55877	.83366	.55827	.83252
13.9	.55852	.83323	.55800	.83207
14.0	.55827	.83280	.55774	.83161
14.1	.55802	.83237	.55747	.83115
14.2	.55776	.83193	.55720	.83068
14.3	.55750	.83149	.55693	.83022
14.4	.55724	.83105	.55666	.82975
14.5	.55698	.83060	.55639	.82928
14.6	.55671	.83014	.55611	.82880
14.7	.55645	.82969	.55583	.82831
14.8	.55618	.82923	.55555	.82783
14.9	.55590	.82877	.55527	.82735
15.0	.55563	.82831	.55499	.82687
15.1	.55536	.82784	.55471	.82638
15.2	.55509	.82737	.55442	.82589
15.3	.55481	.82690	.55414	.82540
15.4	.55453	.82643	.55385	.82490
15.5	.55425	.82596	.55356	.82440
15.6	.55397	.82549	.55327	.82390
15.7	.55369	.82501	.55297	.82339
15.8	.55340	.82453	.55268	.82289
15.9	.55312	.82405	.55239	.82238
16.0	.55283	.82356	.55209	.82187
16.1	.55254	.82307	.55179	.82135
16.2	.55225	.82258	.55148	.82083
16.3	.55196	.82209	.55117	.82031
16.4	.55167	.82160	.55087	.81979
16.5	.55138	.82110	.55057	.81926
16.6	.55109	.82061	.55026	.81873
16.7	.55079	.82011	.54995	.81821
16.8	.55050	.81962	.54964	.81768
16.9	.55020	.81912	.54933	.81715
17.0	.54990	.81862	.54902	.81661
17.1	.54960	.81811	.54870	.81607
17.2	.54929	.81759	.54839	.81552
17.3	.54898	.81707	.54807	.81497
17.4	.54867	.81655	.54774	.81442
17.5	.54837	.81604	.54742	.81387
17.6	.54806	.81552	.54710	.81333
17.7	.54775	.81500	.54677	.81277
17.8	.54744	.81448	.54645	.81222
17.9	.54713	.81396	.54612	.81166
18.0	.54682	.81344	.54579	.81109

Lead angle, λ	3-start threads		4-start threads	
	w_1	$(C+c)_1$	w_1	$(C+c)_1$
1	6	7	8	9
deg	*in*	*in*	*in*	*in*
18.0	.54682	.81344	.54579	.81109
18.1	.54651	.81291	.54546	.81053
18.2	.54619	.81238	.54513	.80997
18.3	.54588	.81185	.54480	.80940
18.4	.54556	.81132	.54447	.80883
18.5	.54524	.81078	.54414	.80826
18.6	.54492	.81024	.54380	.80768
18.7	.54459	.80970	.54345	.80710
18.8	.54427	.80916	.54311	.80652
18.9	.54394	.80861	.54277	.80594
19.0	.54361	.80805	.54242	.80535
19.1	.54328	.80749	.54208	.80477
19.2	.54295	.80694	.54173	.80418
19.3	.54261	.80638	.54138	.80358
19.4	.54227	.80582	.54103	.80298
19.5	.54193	.80526	.54067	.80238
19.6	.54160	.80470	.54032	.80178
19.7	.54126	.80414	.53997	.80118
19.8	.54092	.80358	.53961	.80057
19.9	.54058	.80301	.53925	.79997
20.0	.54025	.80245	.53889	.79936
20.1	----------	----------	.53852	.79874
20.2	----------	----------	.53816	.79812
20.3	----------	----------	.53779	.79750
20.4	----------	----------	.53743	.79689
20.5	----------	----------	.53706	.79627
20.6	----------	----------	.53669	.79564
20.7	----------	----------	.53632	.79502
20.8	----------	----------	.53595	.79440
20.9	----------	----------	.53558	.79377
21.0	----------	----------	.53521	.79314
21.1	----------	----------	.53484	.79251
21.2	----------	----------	.53446	.79187
21.3	----------	----------	.53408	.79123
21.4	----------	----------	.53370	.79059
21.5	----------	----------	.53332	.78994
21.6	----------	----------	.53294	.78930
21.7	----------	----------	.53255	.78865
21.8	----------	----------	.53217	.78801
21.9	----------	----------	.53178	.78736
22.0	----------	----------	.53139	.78670
22.1	----------	----------	.53100	.78604
22.2	----------	----------	.53061	.78539
22.3	----------	----------	.53022	.78473
22.4	----------	----------	.52983	.78406
22.5	----------	----------	.52943	.78339
22.6	----------	----------	.52903	.78272
22.7	----------	----------	.52863	.78205
22.8	----------	----------	.52823	.78138
22.9	----------	----------	.52783	.78071
23.0	----------	----------	.52743	.78004

NOTE.—This table courtesy of the Van Keuren Co.

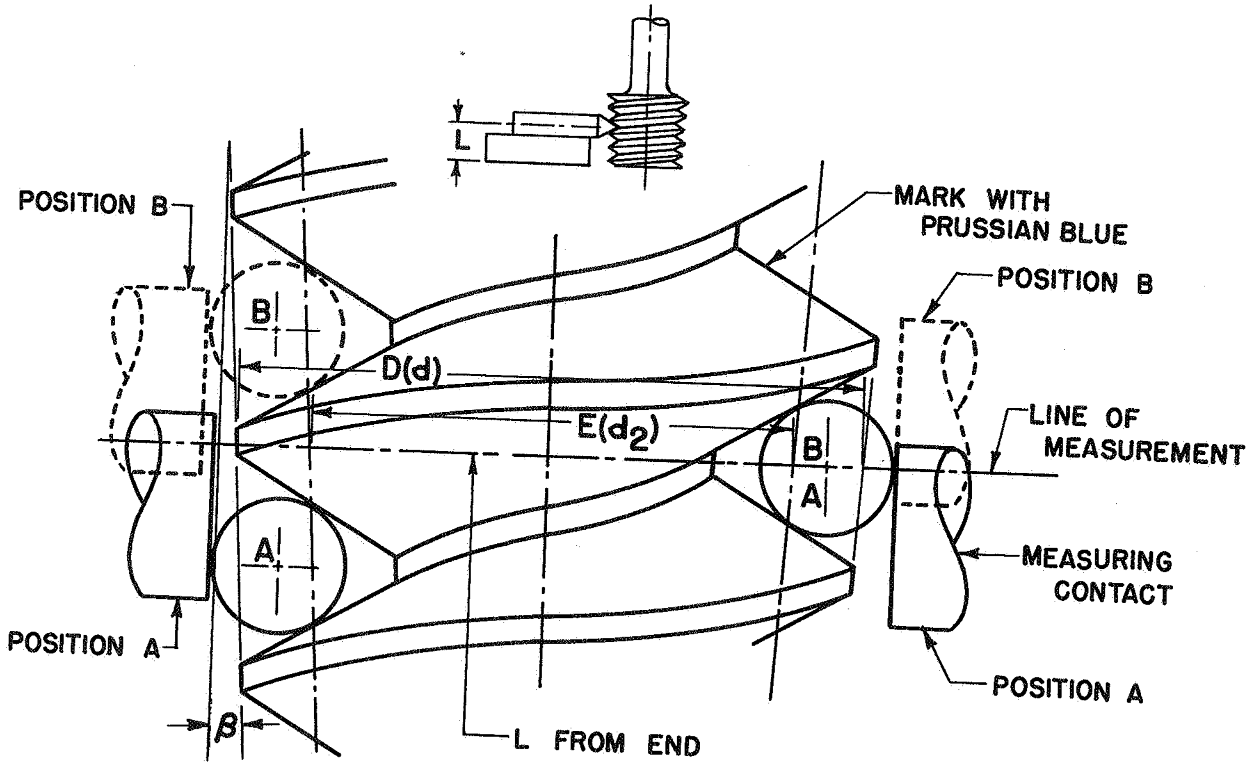

FIGURE A4.5. *Measurement of pitch diameter of taper thread gages by the 2-wire method.*

6. MEASUREMENT OF PITCH DIAMETER OF USA STANDARD TAPER THREADS

The pitch diameter of a taper thread plug gage is measured in much the same manner as that of a straight thread gage, except that a definite position at which the measurement is to be made must be located. A point at a known distance, L, from the reference end of the gage is located by means of a combination of precision gage blocks and the cone point furnished as an accessory with these blocks, as shown in the inset in figure A4.5. The gage is set vertically on a surface plate, the cone point is placed with its axis horizontal at the desired height, and the plug is turned until the point fits accurately into the thread. The position of this point is marked carefully with a pencil or a bit of prussian blue.

6.1. TWO-WIRE METHOD.—Assuming that the measurement is to be made with a horizontal comparator, the gage is set in the comparator with its axis vertical, that is, the line of measurement and the thread axis are perpendicular to each other. The measurement is made with two wires, as shown in figure A4.5, one of which is placed in the thread to make contact at the same axial section of the thread as was touched by the cone point. This wire is designated the fixed wire. The second wire is placed in the thread groove, on the opposite side of the gage, which is next above the fixed wire, and the measurement over the wires is made. The second wire is then placed in the thread groove next below the fixed wire, and a second measurement is made. The average of these two measurements is M_w, the measurement over the wires at the position of the fixed wire.

The general formula for a taper thread, corresponding to formula (3) is

$$E = M_w + \frac{\cot\alpha - \tan^2\beta\tan\alpha}{2n} - w\left(1 + \operatorname{cosec}\alpha + \frac{\tan^2\lambda'\cos\alpha\cot\alpha}{2}\right) \quad (6)$$

in which

E = pitch diameter
M_w = measurement over wires
β = half angle of taper of thread
n = number of threads per inch = $1/p$
α = half angle of thread
w = mean diameter of wires
λ' = wire angle.

The term

$$\frac{\cot \alpha - \tan^2 \beta \tan \alpha}{2n}$$

is the exact value of the depth of the fundamental triangle of a taper thread, which is less than that of the same-pitch thread cut on a cylinder. For steep-tapered thread gages, having an included taper larger than 0.75 in/ft this more accurate term should be applied. For such a thread, which has a small lead angle, formula (6) takes the form

$$E = M_w + \frac{\cot \alpha - \tan^2 \beta \tan \alpha}{2n} - w(1 + \operatorname{cosec} \alpha) \quad (7)$$

Otherwise, as for USA Standard taper pipe threads having an included taper of 0.75 in/ft, the simplified formula (5)

$$E = M_w + \frac{0.86603}{n} - 3w$$

for 60° threads may be used. This simplified formula gives a value of E that is 0.00005 in larger than that given by the above general formula (6) for the 2.5–8 USA Standard taper pipe thread, the worst case in this thread series.

The pitch diameter at any other point along the thread, as at the gaging notch, is obtained by multiplying the distance parallel to the axis of the thread, between this point and the point at which the measurement was taken, by the taper per inch, then adding the product to or subtracting it from the measured pitch diameter according to the direction in which the second point is located with respect to the first.

6.2. Three-Wire Method.—Depending on the measuring facilities available or other circumstances, it is sometimes more convenient to use three wires. In such cases measurement is made in the usual manner, but care must be taken that the measuring contacts touch all three wires, as the line of measurement is not perpendicular to the axis of the screw when there is proper contact. (See fig. A4.6.)

On account of this inclination, the measured distance between the axes of the wires must be multiplied by the secant of the half angle of the taper of

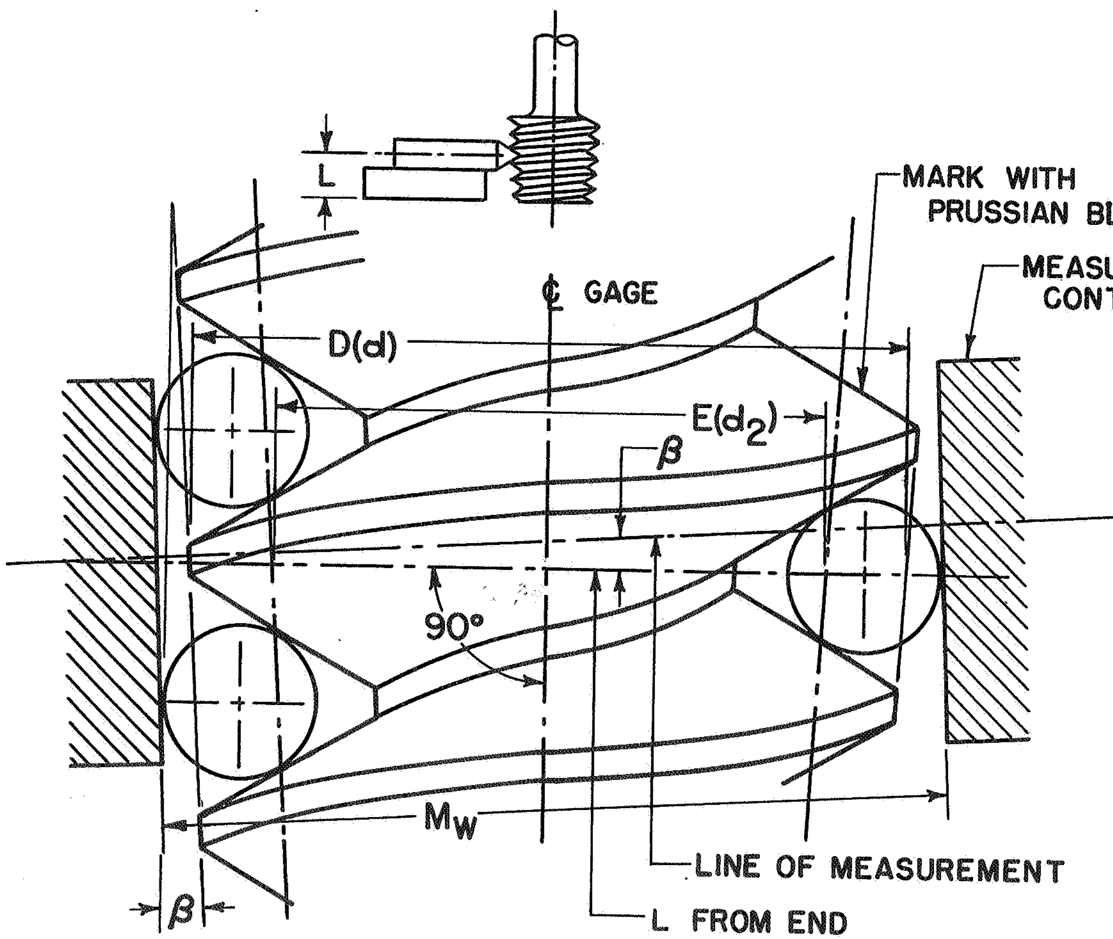

Figure A4.6. *Measurement of pitch diameter of taper thread gages by the 3-wire method.*

the thread. The formula for the pitch diameter of any taper thread plug gage, the threads of which are symmetrical with respect to a line perpendicular to the axis, then has the form corresponding to formula (4):

$$E=(M_w-w)\sec\beta+\frac{\cot\alpha}{2n}-w\ \mathrm{cosec}\ \alpha \qquad (8)$$

in which β = half-angle of taper of thread. Thus the pitch diameter of a USA Standard pipe-thread gage having correct angle (60°) and taper (0.75 in/ft) is then given by the formula

$$E=1.000\,49(M_w-w)+0.866\,03p-2w \qquad (9)$$

An adaption of the three-wire method is frequently used to reduce the time required when the pitch diameter of a number of gages of the same size is to be measured. Only light gages, up to about 1 in nominal size, can be measured accurately by this method. The gage is supported on two wires placed several threads apart, which are in turn supported on a taper thread testing fixture. The third wire is placed in the threads at the top of the gage and measurement is made from the top of this wrie to the bottom of the fixture with a vertical comparator having a flat anvil, using a gage block combination as the standard. The fixture consists of a block, the upper surface of which is at an angle to the base plane equal to the nominal angle of taper of the thread, 2β. Thus the element of the cone at the top of the thread gage is made parallel to the base of the instrument. The direction of measurement is not perpendicular to the axis of the gage but at an angle, β, from perpendicularity. A stop is provided at the thick end of the block with respect to which the gage is positioned on the fixture. As the plane of the end of the gage may not be perpendicular to the axis, a roll approximately equal to the diameter of the gage should be inserted between the stop and the gage to assure contact at the axis of the gage. For a given fixture and roll, a constant is computed which, when subtracted from the measured distance from the top of the upper wire to the base plane, gives M corresponding to the pitch diameter, E_0, at the small end of the gage. E_0 is then determined by applying formula (8) or (9).

6.3. Four-Wire Method.—A four-wire method of measurement that yields measurements of the pitch diameter, E_0, at the small end of the gage, and the half-angle of taper, β, is also sometimes used. This method is illustrated in figure A4.7 and requires four thread wires of equal diameter, a pair of gage blocks of equal thickness, and two pairs of rolls of different diameters, the rolls of each pair being equal in diameter. Two measurements, M_1 and M_2, are made over the rolls and formulas are applied as follows:

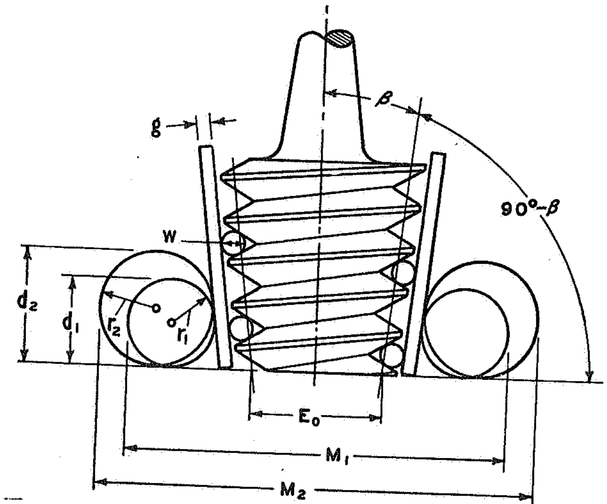

Figure A4.7. *Measurement of pitch diameter of taper thread gages by the 4-wire method.*

$$\cot\frac{90-\beta}{2}=\frac{M_2-M_1+d_1-d_2}{d_2-d_1} \qquad (10)$$

$$M_w=M_2-d_2\left(1+\cot\frac{90°-\beta}{2}\right)-2g\sec\beta \qquad (11)$$

in which

M_2 = measurement over larger rolls
M_1 = measurement over smaller rolls
d_2 = diameter of larger rolls
d_1 = diameter of smaller rolls
β = actual half-angle of taper of thread
g = thickness of each gage block.

To determine E_0, the pitch diameter at the small end of the gage, M_w, as determined from formula (11), is substituted in formula (6) or (7).

The errors of measurement by this method may be slightly but not significantly larger than by the other methods described, on account of elastic deformations of the rolls and gage blocks under the measuring force, and differing conditions of loading of the thread wires.

7. MEASUREMENT OF PITCH DIAMETER OF THREAD RING GAGES

The application of direct methods of measurement to determine the pitch diameter of thread ring gages presents serious difficulties, particularly in securing proper contact load when a high degree of precision is required. The usual practice is to fit the ring gage to a threaded setting plug. When the thread ring gage is of correct lead, angle, and thread form, within close limits, this method is satisfactory and represents standard practice in the United States. It is the only method available for small sizes of threads. For the larger sizes, various more or less satisfactory methods have been devised, but none of these have found wide application.

UNITED STATES DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

HANDBOOK H28

SCREW-THREAD STANDARDS

FOR FEDERAL SERVICES

APPENDIX A5

1969

DESIGN OF SPECIAL THREADS

1. GENERAL

In general, any given problem in thread design may be susceptible to several more or less satisfactory solutions based on the preliminary selection of certain elements of the design and the proper adjustment of the other elements. In other words, thread design is to a large extent empirical and is partially based on previous experience with similar designs and the judgment of the designer. Accordingly, it is not practicable to present a definite system of approach to the design of a threaded assembly but merely to present a discussion of various design factors.

The interrelation of length of engagement, minimum major diameter of the external thread, maximum minor diameter of the internal thread, and the strength of the assembled thread needs to be understood and carefully considered in order to produce the optimum design of a special thread. It is not economical to use either a length of thread engagement which is longer than required or shorter than that which will develop the full strength of the externally threaded member. Other factors, such as control of tap breakage, proper seating of a threaded part on a shoulder, the prevention of cross threading, conditions of loading when the assembled parts are not concentric, and possible collapse of a hollow externally threaded member, require careful analysis and adjustment of the design with respect to selection of the diameter-pitch combination, the class of thread, length of engagement, and major and minor diameter tolerances.

In redesigning threads from American National to Unified standards, it should be remembered that exact correspondence between the old and new class numbers does not exist. For most, but not all, diameter-pitch combinations, the combined tolerances and allowances of the Unified classes are somewhat larger than American National classes of corresponding number. Recommended procedure is to convert the thread to the corresponding class of Unified thread, compare the new major, pitch, and minor diameter tolerances with the old tolerances, and then give careful consideration to the desirability of the new limits of size.

Taking, for example, the conversion of a class 1 thread to classes 1A and 1B: Under ordinary conditions where the thread is being used only as a simple fastener and the length of engagement is normal, such substitution may be made. If, for any reason, the previously specified tolerances may not be exceeded, it may be necessary to specify class 2A or 2B or both. Also, if the thread must carry a high axial stress or if concentricity of the two mating parts is a factor, the conversion should be from class 1 to classes 2A and 2B.

A close fitting thread assembly under some conditions may fail, whereas the cause of failure may be eliminated by providing a looser fit. A cap screw that seats only on one side of the bearing surface under the head may break off when the screw is tightened. When a screw has a large bearing surface under the head or when the head must be square with a projecting pin, sufficient pitch diameter clearance must be provided to allow for any out-of-squareness of the screw axis with the bearing surface under the head. Thus, as large a pitch diameter tolerance as possible, together with providing proper tolerances on squareness of face with the thread axis where seating is required, may avoid the necessity for specifying a heat treated bolt.

2. ECCENTRICITY OF ASSEMBLY AND CROSS THREADING

In assembly and use, the combined tolerances and allowances on both mating parts should not allow threads to disengage on one side when assembly is eccentric. The axis of the internal thread can be displaced radially from coincidence with the axis of the external thread by an amount equal to the sum of the pitch diameter tolerances and the allowance. This radial displacement may be sufficient so that the flank contact is entirely on one side and on the opposite side the crest of the external thread will be in line with the crest of the internal thread with the following results when the screw is constrained in such a position in a tapped hole: (1) There will be danger of crossing the threads in starting, and (2) the screw may pull out of the hole when tension is exerted in this constrained position. The minimum amount of overlap is arbitrary and controversial, but the following general rule can be used in lieu of more specific data:

As the first step to assure the minimum safe overlap on both sides when the assembly is concentric, the difference between the minimum major diameter of the external thread and the maximum minor diameter of the internal thread should not be less than twice the addendum of the external thread ($0.75H$, table 2.1). Otherwise stated, the sum of the major-diameter tolerance and allowance, if any, of the external thread and the minor-diameter tolerance of the internal thread should not be greater than 4/3 the addendum of the external thread, $0.5H$, table 2.1. This provides for a minimum of 50 percent thread engagement. As the second step, to assure the minimum safe overlap on one side when the assembly is eccentric, the difference between the maximum pitch diameter of the internal thread and the minimum pitch diameter of the external thread should not be greater than twice the addendum of the external thread (0.75H, table 2.1). Otherwise stated, the sum of the pitch-diameter tolerances of both threads and the allowance, if any, should not be greater than twice the addendum of the external thread, (0.75H, table 2.1). This provides for an eccentric assembly condition equal to the addendum of external thread (0.375H, table 2.1) and zero minimum overlap on one side. If the results from the limits of size selected violate the above rules, the tolerances should be reduced by using a closer class of tolerance, assuming tolerances consistent with manufacturing possibility, or a coarser pitch should be used to increase the amount of overlap. The major-diameter tolerance of the external thread or minor-diameter tolerance of the internal thread should not be less than the pitch-diameter tolerance of the respective thread to maintain thread form.

It should be noted that, if the tolerance on the minor diameter of the internal thread must necessarily be large, the major diameter of the external thread must be held close to the maximum major diameter and vice versa.

3. STRENGTH FACTORS

CRITICAL AREAS—The critical areas of mating threads, as related to the tensile strength of the thread assembly, are: The effective cross-sectional area, or stress area, of the external thread, (2) the shear area of the external thread that depends principally on the minor diameter of the tapped hole, and (3) the shear area of the internal thread that depends principally on the major diameter of the external thread. The formulas for tensile stress area and thread shear area are shown below. These areas are indicated in figure A5.1.

Tensile Stress Area.—The tensile stress area is the assumed area of an external threaded part that is used for the purpose of computing the tensile strength.

Direct Tensile Stress.—When parts are subjected only to a direct tensile stress the assumed area applicable to steel parts *up to 180,000 psi* used in calculating the ultimate strength is computed from the following formula:

$$A_s = 3.1416\left(\frac{E}{2} - \frac{3H}{16}\right)^2$$

or

$$A_s = 0.7854(D - 0.9743/n)^2$$

where

E = basic pitch diameter
D = basic major diameter
n = threads per inch

For $3H/16$, see table 2.1. Tabulated stress areas are listed in tables 2.8 through 2.18.

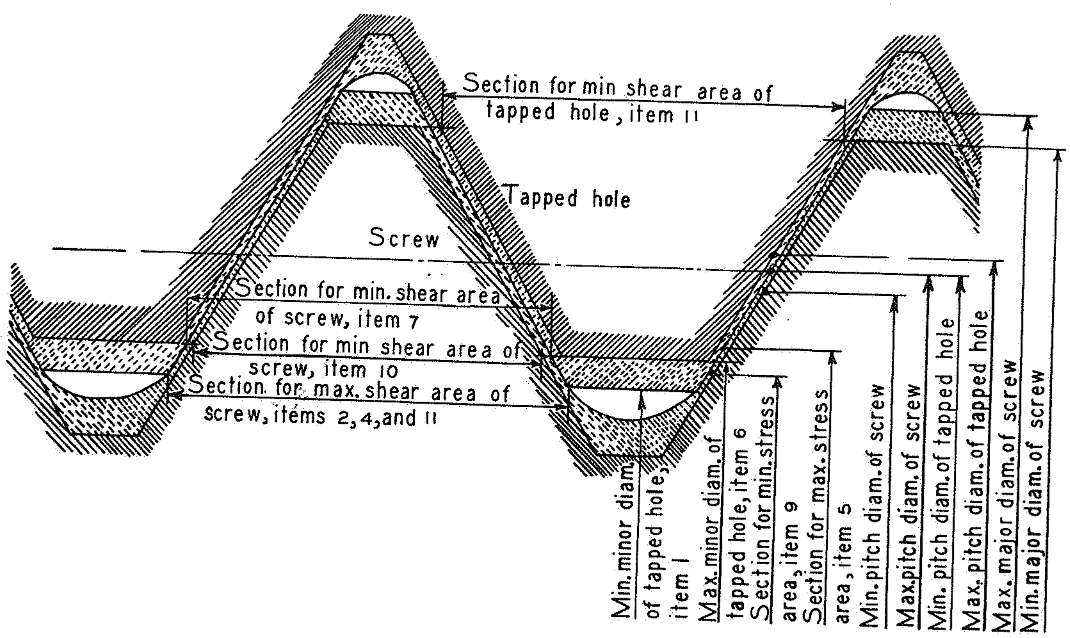

FIGURE A5.1. *Critical sections in a thread assembly.*

See table A5.2 for formulas corresponding to item numbers.

TABLE A5.2. *Data for determining strength factors in special thread design*

NOTATION

D = basic major diameter.
D_s = major diameter of external thread.
K_n = minor diameter of internal thread.
T_{Kn} = tolerance on minor diameter of internal thread.
T_{Es} = tolerance on pitch diameter of external thread.
G = allowance on all diameters of external thread.
L_e = length of thread engagement.
A_s = stress area of external thread.
S_s = area in shear on external thread in line with K_n.
S_n = area in shear in internal thread in line with D_n.

CONSTANTS

$C_1 = \frac{3}{4}\pi = 2.356$	Threads per inch, n														
	40	36	32	28	27	24	20	18	16	14	12	10	8	6	4
$C_2=\frac{5}{8}\frac{\cot 30°}{n}=\frac{1.08253}{n}=$	0.0271	0.0301	0.0338	0.0387	0.0401	0.0451	0.0541	0.0601	0.0677	0.0773	0.0902	0.1083	0.1353	0.1804	0.02706
$C_3=\frac{9}{16}\frac{\cot 30°}{n}=\frac{0.974279}{n}=$	.0244	.0271	.0304	.0348	.0361	.0406	.0487	.0541	.0609	.0696	.0812	.0974	.1218	.1624	.2436
$C_4=n \tan 30°=0.57735n=$	23.09	20.78	18.48	16.17	15.59	13.86	11.55	10.39	9.328	8.083	6.928	5.774	4.619	3.464	2.309
$C_5=\pi n \tan 30°=1.8138n$	72.55	65.30	58.04	50.79	48.97	43.53	36.25	32.65	29.02	25.39	21.76	18.14	14.51	10.88	7.255

FORMULAS

MAXIMUM MATERIAL FOR BOTH EXTERNAL AND INTERNAL THREADS

Item

1. $K_n \min = D - C_2$.
2. Max area in shear of external thread per inch = S_s max per inch = $C_1 K_n \min$.
3. Min length of thread engagement, $L_e \min = \frac{L_e}{D} \times D_s \max$, with $\frac{L_e}{D}$ taken from graph, figure A5.3.
4. Area in shear of external thread in length L_e min = S_s max per inch $\times L_e$ min (= item 2 × item 3).
5. Max stress area of external thread = $A_s \max = \frac{S_s \max \text{ per inch} \times L_e \min}{2} \left(= \frac{1}{2} \text{ item } 4\right) = \frac{C_1 K_n \min \times \frac{L_e}{D} \times D_s \max}{2}$.

MAXIMUM MATERIAL EXTERNAL THREAD, K_n MAXIMUM

6. $K_n \max = K_n \min + T_{Kn}$.
7. Min area in shear of external thread per inch = S_s min per inch = $K_n \max (C_1 - C_5 T_{Kn})$.
8. L_e required to develop full strength of external thread for T_{Kn} selected $= \frac{2 A_s \max}{S_s \min \text{ per inch}} = \left(\frac{2 \times \text{item } 5}{\text{item } 7}\right)$ or $= \left(\frac{\text{item } 4}{\text{item } 7}\right)$.

MINIMUM MATERIAL FOR BOTH EXTERNAL AND INTERNAL THREADS

9. Min stress area of external thread = $A_s \min = 0.7854 [D - C_3 - (T_{Es} + G)]^2$.
10. Min area in shear of external thread in length $L_e = S_s \min = K_n \max [C_1 - C_5(T_{Kn} + T_{Es} + G)] L_e$, or $= \pi K_n \max [0.75 - C_4(T_{Kn} + T_{Es} + G)] L_e$.
11. Min area in shear of internal thread in length $L_e = S_n \min = \pi D_s \min [0.875 - C_4(T_{Ds} + T_{En} + G)] L_e$.

MINIMUM TAPPED HOLE, D_s MINIMUM, WHEN TAPPED MATERIAL IS WEAKER THAN SCREW MATERIAL

12. $R_1 = \frac{\text{area in shear of screw in length } L_e}{\text{area in shear of tapped hole in length } L_e} = \left(\frac{\text{item } 4}{\text{item } 11}\right) = \frac{0.75 K_n \min}{D_s \min [0.875 - C_4 (T_{Ds} + T_{En} + G)]}$
13. $R_2 = \frac{\text{ultimate tensile strength of tapped material}}{\text{ultimate tensile strength of screw material}}$.
14. If $R_2 < R_1$, then L_e required = L_e for T_{Kn} selected $\times \frac{R_1}{R_2} = \left(\frac{\text{item 8} \times \text{item 12}}{\text{item 13}}\right)$.

Combined Tensile Stress.—When parts are subject to a direct tensile stress plus a torsional stress due to tightening the nut or bolt head, it is necessary to consider the combined shear and tensile stresses when calculating the strength of the externally threaded part. It is recommended that the combined stresses be computed on the basis of the section at the minimum minor diameter of the external thread. The direct tensile stress is given by the formulas:

$$S_t = F/A$$
$$A_r = 0.7854[(K_s \min)^2 - d^2]$$

where

A_r = area in sq in at the minimum minor diameter.
F = axial load on externally threaded parts in lb.

The direct torsional stress is given by the formulas:

$$S_s = T_1/Z_p$$

$$Z_p = 0.1963 \frac{[(K_s \min)^4 - d^4]}{K_s \min}$$

where

T_1 = wrench torque transmitted through the threaded section, approximately equal to half of the total wrench torque in lb-in.
Z_p = polar section modulus in in³
$K_s \min$ = minimum minor diameter of external thread in in.
d = inside diameter of externally threaded part in in; if part is solid, d = zero.

The combined shear stress in psi is given by the formula:

$$S_s' = \sqrt{\left(\frac{S_t}{2}\right)^2 + (S_s)^2}$$

The combined tensile stress in psi is given by the formula:

$$S_t' = S_s' + S_t/2$$

Having once determined the combined stresses due to a given set of conditions for wrench torque and coefficient of friction, other combined stresses will be directly proportional to the wrench torque.

Thread Shear Area.—The diameter corresponding to the effective thread shear area will vary with the relative unit tensile strengths of the materials of the internal and external threads. When the external and internal threads are manufactured from materials of equal unit tensile strength, failure will usually take place simultaneously in both threads at or near a diameter equal to the basic pitch diameter. The shear area (AS) for external and internal threads made of such materials can be computed from the following formula:

$$AS = 3.1416E\,\frac{L_e}{2}$$

where

E = basic pitch diameter
L_e = length of engagement at basic pitch diameter.

When the unit tensile strength of the external thread material greatly exceeds that of the internal thread material, as in the case of a threaded hole in a cast aluminum block mated with a 100,000 psi ultimate strength material bolt, the shear area of the internal thread (AS_n) can be computed from the following formulas:

(1) For simplified calculations that will provide shear areas within about 5 percent of those given by the precise formula shown below, the shear area of the internal thread may be computed as follows:

$$AS_n = 3.1416E\,\frac{3L_e}{4}$$

where L_e = length of engagement at the basic pitch diameter.

(2) The precise equation for shear area of the internal thread at a diameter equal to the minimum major diameter of the external thread is as follows:

$$AS_n = 3.1416nL_eD_s\min\left[\frac{1}{2n}+0.57735(D_s\min-E_n\max)\right]$$

where

n = number of threads per inch
$D_s \min$ = minimum major diameter of external thread
$E_n \max$ = maximum pitch diameter of internal thread
L_e = length of engagement at minimum major diameter of external thread. (Use L_e at basic pitch diameter for simplicity; this is conservative.)

When the unit tensile strength of the internal thread material greatly exceeds that of the external thread material, the shear area of the external thread (AS_s) can be computed from the following formulas:

(1) For simplified calculations for diameters 0.250 in and larger, that will provide shear areas within about 5 percent of those given by the precise formula shown below, the shear area of the external thread may be computed as follows:

$$AS_s = 3.1416E\,\frac{5L_e}{5}$$

where L_e = length of engagement at the basic pitch diameter.

(2) The precise equation for shear area of the external thread at a diameter equal to the maximum minor diameter of the internal thread is as follows:

$$AS_s = 3.1416nL_eK_n\max\left[\frac{1}{2n}+0.57735(E_s\min-K_n\max)\right]$$

where

$K_n \max$ = maximum minor diameter of internal thread.
$E_s \min$ = minimum pitch diameter of external thread.

If failure of a thread assembly should occur it is desirable that the external thread (screw) will break rather than that either the external or internal thread will strip. In other words, the length of thread engagement shall be sufficient to develop the full strength of the screw. Thus, the length of internal thread and the dimensions of this thread, particularly its minor diameter, should be such that, taking into account a possible difference in strength of material of the internal and external threads, the threaded portion of the external thread will break before either the external or internal threads strip.

Length of Thread Engagement—The length of engagement of a threaded unit that will develop maximum strength of an assembly threaded with external and internal threads manufactured from materials of near or equal unit tensile strength may be computed from the following formula, which incorporates the factor "half" relation of unit shearing strength to unit tensile strength:

$$L_e = 4A_s/3.1416E$$

where

$$A_s = 3.1416\left(\frac{E}{2}-\frac{3H}{16}\right)^2$$

When the unit tensile strength of the external thread materially exceeds that of the internal thread, the required length of engagement to develop maximum strength may be computed from the following formula, which is also based on the shear area being twice the tensile stress area:

$$L_e = \frac{2A_s}{3.1416nD_s\min\left[\frac{1}{2n}+0.57735(D_s\min-E_n\max)\right]}$$

Likewise, when the unit tensile strength of the internal thread materially exceeds that of the external thread, the following formula should be used:

$$L_e = \frac{2A_s}{3.1416nK_n \max\left[\frac{1}{2n}+0.57735(E_s \min - K_n \max)\right]}$$

The factor 2 used in the numerator of this formula means that it is assumed that the area in shear must be twice the tensile stress area to develop the full strength of the screw. This assumption is based on experiments made by the National Bureau of Standards in 1929, in which it was found that for hot-rolled and cold-rolled steel, and brass screws and nuts, this factor varied from 1.7 to 2.0. Taking the factor as 2 provides in general a small factor of safety against stripping of the threads.

To facilitate the application of this formula various notations, constants, and formulas applicable to the determination of the relation of critical areas to thread dimensions are given in table A5.2 and are discussed below.

(*a*) *Length of engagement determined by shear area of external thread.*—Formula 8, table A5.2, gives the length of engagement required to develop the full strength of the screw when the strength of the material in which the hole is tapped is the same as, or slightly less than, the strength of the material of the screw. The value of L_e thus obtained is sufficient for a permanently-fastened connection. If, however, the screw is an adjusting or lead screw, or if the connection will be frequently unscrewed, L_e should be increased to allow for the expected wear on the flanks of the threads during the useful life of the components.

For tapped holes in sheet metal, the maximum size of the screw to be specified should be such that the thickness of sheet equals the L_e required to develop full strength. In order to use the largest possible screw, it is necessary that the tolerance, T_{Kn}, on the minor diameter of the hole should be the practical minimum. If it should prove to be impracticable to reduce the minor diameter tolerance to such a value, it may be necessary to decrease the minimum minor diameter of the internal thread and to increase the minor diameter tolerance by the same amount. If this is done, the maximum minor diameter of the screw must be reduced by the same amount to prevent interference, and the minor diameter of the "go" thread ring gage must likewise be decreased, as this is the only control of the minor diameter of the screw. In all such cases, where dimensions are altered from those calculated according to the standard, the threads should be designated as specified in section 2. (See under "Designating threads having modified crests" in that section.)

(*b*) *Length of engagement determined by shear area of internal thread.*—The ratio of the area in shear in the screw and the area in shear in the tapped hole is given by formula 12, table A5.2. This ratio, R_1, will usually be less than 1 and the strength of the material of the tapped hole can be less than the strength of the material of the screw by this ratio with no indicated increase in L_e by formula 8. If, however, the ratio

$$R_2 = \frac{\text{ultimate tensile strength of tapped material}}{\text{ultimate tensile strength of screw material}}$$

is less than R_1, then L_e should be multiplied by R_1/R_2 to provide sufficient length of thread to prevent stripping of the threads in the tapped hole.

For retaining collars on shafts where the expected axial force resisted by the collar is appreciably less than the tensile force that the shaft itself is capable of resisting, L_e need only be long enough to withstand the expected axial force on the collar. If F_c is the axial force to be carried by the collar and *uts* is the tensile strength of the material of the shaft in pounds per square inch, then the length of thread engagement required on the shaft is equal to $2F_c/(uts \times S_s \min)$, where S_s min is given by formula 7, when the strength of material of the collar is the same or slightly less than the strength of material of the shaft. Ratios R_1 and R_2 should be computed as previously explained to determine whether or not a greater length is required to prevent stripping of the threads in the collar.

(*c*) *Hollow externally threaded parts.*—For screws with through axial holes, the length of engagement required is of course less than if the screw is solid. For this condition, formula 8 becomes

$$L_e \max = \frac{2(A_s \max - A_n \max)}{S_s \min \text{ per inch}}$$

where A_n is the cross-sectional area of the hole.

However, as the wall thickness of either or both the internal and external members becomes thin, the tendency of the external member to enlarge and the internal member to neck down in the thread means that an L_e greater than given by the above formula must be used, also that the tolerances on minor diameter of the internal thread and major diameter of the external thread, T_{Kn} and T_{Ds}, must be small to obtain the maximum practicable depth of thread engagement. For components having threads on thin-wall tubing, tests under actual working conditions should be made to determine proper selection of wall thicknesses, length of engagement, and pitch of thread.

4. THREAD PROPORTIONS IN RELATION TO TAPPING

In the production of threads it is considered impractical to tap a thread unless its diameter is greater than six times the basic thread height; therefore, when the ratio of D to H is less than 4.5, the use of a larger diameter, a finer pitch of thread, or both, should be considered.

The size of K_n is a factor in controlling tap breakage. Tap breakage is infrequent if the diameter of the tap is over 0.5 in or if the length of thread to be tapped is less than $0.5D$. For sizes less than 0.5 in and length of thread over $0.5D$, tap breakage can be minimized by use of a large K_n, that is T_{Kn} maximum. However, this means that L_e may have to be increased to develop the full strength of the screw.

5. EXAMPLES OF THREAD DESIGN

The design of special threads for particular purposes is illustrated by the following examples:

Example: A gun barrel is subjected to an internal explosive pressure that produces a tensile stress in the threaded end. The length of engagement of the threads should be sufficient to produce a minimum area in shear on the threads of the screw in line with the minor diameter of the tapped hole threads equal to twice the maximum stress area of the threaded portion of the barrel.

Assume that the thread on the barrel is 1.500–8UN–2A and the minimum internal diameter of the barrel at the threaded end is 0.792 in.

In table 2.21 will be found the following maximum dimensions of the external thread:

$$D_s \text{ max} = 1.4978 \text{ in}$$
$$E_s \text{ max} = 1.4166 \text{ in}$$
$$K_s \text{ max} = 1.3444 \text{ in.}$$

From table 2.21, K_n min = 1.365 in. If we select the tolerance for minor diameter of hole $T_{Kn} = 0.0250$ in, K_n max will equal $1.365 + 0.025 = 1.390$, which will permit the use of a 1.375 in tap drill.

The minimum area in shear per inch can be computed, using formula 7, table A5.2:

$$S_s \text{ min} = K_n \text{ max}(C_1 - C_5 T_{Kn})$$
$$= 1.390(2.356 - 14.51 \times 0.025)$$
$$= 2.7706 \text{ in.}^2$$

The maximum stress area of the external thread, if solid, using formula 5, table A5.2, is

$$A_s \text{ max} = 0.5\left(C_1 K_n \text{ min} \times \frac{L_e}{D} \times D_s \text{ max}\right)$$

$$\frac{L_e}{D} \text{ from chart, fig. A5.3} = 0.6185,$$

$$= 0.5(2.356 \times 1.365 \times 0.6185 \times 1.4978)$$
$$= 1.4896$$

Area of minimum center hole

$$= (\pi/4) \times 0.792^2 = 0.4926$$

Max stress area of external threaded member

$$1.4896 - 0.4926 = 0.9970$$

Length of thread engagement required

$$= L_e = \frac{2 \times \text{max } A_s}{S_s \text{ min}}$$

$$= \frac{2 \times 0.997}{2.7706}$$

$$= 0.7197 \text{ in.}$$

If a length of engagement of 0.72 in cannot be obtained, the tolerance on minor diameter, T_{Kn}, of the internal thread should be reduced. If a space for a longer length of engagement is available, T_{Kn} can be increased.

Example: The dimension is required of the largest steel cap screw that can be used to hold a bracket on a cast iron body. The tensile strength of the steel is 60,000 psi, the tensile strength of the cast iron 20,000 psi, and the thickness of the cast iron is such that the length of thread engagement cannot exceed 1.750 in. The screws on the top side of the bracket will be in tension. From the ratio of the tensile strengths of the two materials, $R_2 = 20{,}000/60{,}000 = 0.333$, it is evident that the length of the tapped hole thread must be considerably longer than the length of thread engagement required to develop the full strength of the screw. R_1 will be of the order of 0.85 and the length of thread in the tapped hole will be approximately $R_1/R_2 = 0.85/0.333 = 2.55$ times as long as the length required to develop the full strength of the screw. L_e required to develop the full strength of the screw must be of the order of $1.750/2.55 = 0.686$ in.

Inasmuch as the hole is tapped in cast iron, a relatively coarse thread would be required, that is UNC or coarser. For such threads L_e/D, as shown on the chart, figure A5.3, varies between 0.57 and 0.61. Taking $L_e/D = 0.59$, the approximate diameter required is $0.686/0.59 = 1.163$. Try $D = 1\frac{1}{16} = 1.0625$ in. The selected pitch could be either 10 or 8 threads per inch with 8 threads per inch preferred. For a bracket screw, class 2A would be the preferred class.

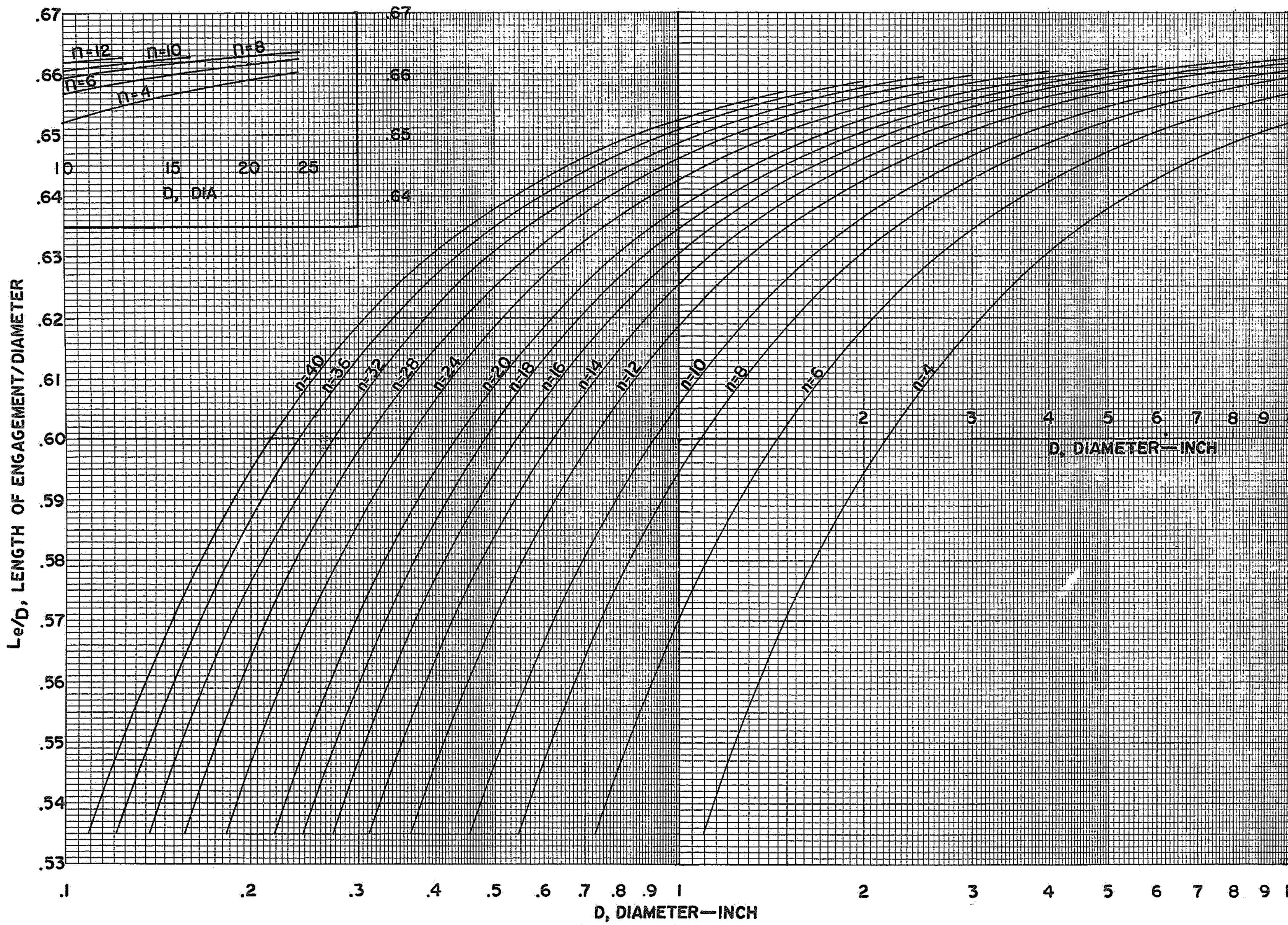

FIGURE A5.3. *Chart for determining minimum length of thread engagement.*

Thus, the screw is 1.0625–8UN–2A and the hole 1.0625–8UN–2B.

Next, read the dimensions of the screw and hole from table 2.21 to determine whether or not the above selection is correct.

Max major diameter of screw, D_s max = 1.0605
Min major diameter of screw, D_s min = 1.0455
Min minor diameter of tapped hole, K_n min = 0.927

The number of 1.0625–8 screws required will depend on the torque that may develop on the bracket that will produce tension in the screws. It should be possible to tighten these screws to the yield strength of the steel without stripping the cast iron threads.

The complete table of dimensions of the tapped hole and screw is (From table 2.21)

Internal thread, 1.0625–8UN–2B

Min major diameter = 1.0625
Min pitch diameter = 0.9813
Max pitch diameter = 0.9902
Min minor diameter = 0.927
Max minor diameter = 0.952

External thread, 1.0625–8UN–2A

Max major diameter = 1.0605
Min major diameter = 1.0455
Max pitch diameter = 0.9793
Min pitch diameter = 0.9725
Max minor diameter = 0.9071

L_e/D from chart, figure A5.3 = 0.5990

$$L_e \min = L_e/D \times D_s \max = 0.5990 \times 1.0605 = 0.6352$$

$$T_{E_n} \text{ (table 2.21)} = 0.0089$$

R_1, table A5.2, formula 12

$$= \frac{0.75 K_n \min}{D_s \min[0.875 - C_4(T_{E_n} + T_{D_s} + G)]}$$

$$= \frac{0.75 \times 0.927}{1.0455[0.875 - 4.619(0.0089 + 0.0150 + 0.0020)]}$$

$$= 0.8803$$

L_e required in hole

$$= L_e \min \times \frac{R_1}{R_2} = 0.6352 \times 0.8803/0.3333 = 1.6777 \text{ in,}$$

which is less than the L_e (1.750 in.) permitted.

UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

HANDBOOK H28

SCREW-THREAD STANDARDS

FOR FEDERAL SERVICES

APPENDIX 6

1957

REFERENCES

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