APPENDIX E

Fits and Tolerances

Fits between parts, as a cylindrical member fitting in a cylindrical hole, influence the accuracy of relative positioning of the members, the ease with which the members can be assembled and disassembled, the ease with which they can slide with respect to each other (with clearance fits), and the load they can sustain without relative motion (with interference fits). Differential thermal expansion is often a factor to be considered in determining appropriate fits. The *tolerance* or permitted variation applied to each dimension influences both function and cost. Unnecessarily small tolerances are an important factor causing excessive cost.

Fits and tolerances are usually specified on the basis of experience with the specific application involved. USAS (ANSI) Standard B4.1-1967 contains detailed recommendations that serve as a valuable guide. Its original predecessor, ASA B4a-1925, provides a simpler guide that is helpful for obtaining an introductory understanding of the subject. It is summarized in Appendix E-1. Classes 1 through 4 are *clearance fits*, Classes 7 and 8 are *interference fits*, and Classes 5 and 6 are known as *transitional fits* because they can be either clearance or interference fits, depending on the random assembly of the parts.

Appendix E-1 illustrates the *basic hole system,* wherein the minimum hole size is chosen as the standard nominal dimension for all classes of fits. Here

d = nominal diameter

h = hole diameter tolerance $= C_h \sqrt[3]{d}$

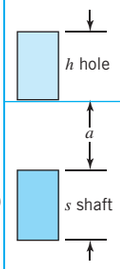
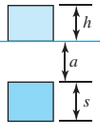
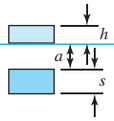
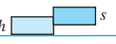
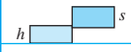
s = shaft diameter tolerance $= C_s \sqrt[3]{d}$

a = allowance (minimum diametral clearance, obtained with maximum shaft and minimum bore dimensions) $= C_a \sqrt[3]{d^2}$

i = average interference, obtained with average shaft and bore diameters $= C_i d$

The bar graphs are to scale for $d = 25$ mm or 1 in.

Appendix E-1 *Fits and Tolerances for Holes and Shafts*

Class of fit	1	2	3	4	5	6	7	8
Bar graph (basic hole system)	 Loose fit	 Free fit	 Medium fit	 Snug fit	 Wringing fit	 Tight fit	 Medium force fit	 Heavy force and shrink fit
C_h	.0216 (.0025)	.0112 (.0013)	.0069 (.0008)	.0052 (.0006)	.0052 (.0006)	.0052 (.0006)	.0052 (.0006)	.0052 (.0006)
C_s	.0216 (.0025)	.0112 (.0013)	.0069 (.0008)	.0035 (.0004)	.0035 (.0004)	.0052 (.0006)	.0052 (.0006)	.0052 (.0006)
C_a	.0073 (.0025)	.0041 (.0014)	.0026 (.0009)	0 (0)				
C_i					0 (0)	.00025 (.00025)	.0005 (.0005)	.0010 (.0010)

Note: Numbers in the table are for use with all dimensions in *millimeters*, except for those in parentheses, which are for use with *inches*.

Appendix E-2 provides the tolerance values for holes and shafts over various size ranges and grades. Appendix E-3 designates the anticipated grade range (and therefore tolerances) provided for a particular machining process. The official American National Standard from which the information in Appendix E-2 and E-3 was taken is ANSI (American National Standards Institute) B4.1-1967(R1999), published by the American Society of Mechanical Engineers (ASME) and sponsored by ASME.

Appendix E-2 *Standard Tolerances for Cylindrical Parts*

Nominal Size Range (in.)	Tolerance Grade									
Over To	4	5	6	7	8	9	10	11	12	13
0 – 0.12	**0.12**	**0.15**	**0.25**	**0.4**	**0.6**	**1.0**	**1.6**	**2.5**	**4**	**6**
0.12 – 0.24	**0.15**	**0.20**	**0.3**	**0.5**	**0.7**	**1.2**	**1.8**	**3.0**	**5**	**7**
0.24 – 0.40	**0.15**	**0.25**	**0.4**	**0.6**	**0.9**	**1.4**	**2.2**	**3.5**	**6**	**9**
0.40 – 0.71	**0.2**	**0.3**	**0.4**	**0.7**	**1.0**	**1.6**	**2.8**	**4.0**	**7**	**10**
0.71 – 1.19	**0.25**	**0.4**	**0.5**	**0.8**	**1.2**	**2.0**	**3.5**	**5.0**	**8**	**12**
1.19 – 1.97	**0.3**	**0.4**	**0.6**	**1.0**	**1.6**	**2.5**	**4.0**	**6**	**10**	**16**
1.97 – 3.15	**0.3**	**0.5**	**0.7**	**1.2**	**1.8**	**3.0**	**4.5**	**7**	**12**	**18**
3.15 – 4.73	**0.4**	**0.6**	**0.9**	**1.4**	**2.2**	**3.5**	**5**	**9**	**14**	**22**
4.73 – 7.09	**0.5**	**0.7**	**1.0**	**1.6**	**2.5**	**4.0**	**6**	**10**	**16**	**25**
7.09 – 9.85	**0.6**	**0.8**	**1.2**	**1.8**	**2.8**	**4.5**	**7**	**12**	**18**	**28**
9.85 – 12.41	**0.6**	**0.9**	**1.2**	**2.0**	**3.0**	**5.0**	**8**	**12**	**20**	**30**
12.41 – 15.75	**0.7**	**1.0**	**1.4**	**2.2**	**3.5**	**6**	**9**	**14**	**22**	**35**
15.75 – 19.69	**0.8**	**1.0**	**1.6**	**2.5**	**4**	**6**	**10**	**16**	**25**	**40**
19.69 – 30.39	0.9	1.2	2.0	3	5	8	12	20	30	50
30.09 – 41.49	1.0	1.6	2.5	4	6	10	16	25	40	60
41.49 – 56.19	1.2	2.0	3	5	8	12	20	30	50	80
56.19 – 76.39	1.6	2.5	4	6	10	16	25	40	60	100
76.39 – 100.9	2.0	3	5	8	12	20	30	50	80	125
100.9 – 131.9	2.5	4	6	10	16	25	40	60	100	160
131.9 – 171.9	3	5	8	12	20	30	50	80	125	200
171.9 – 200	4	6	10	16	25	40	60	100	160	250

Note: Adapted from ANSI B4.1-1967(R1999). Tolerance values are in thousands of an inch. Data in bold face are in accordance with ABC (American–British–Canadian) agreements.

Appendix E-3 *Tolerance Grades Produced from Machining Processes*

Machining Process	Tolerance Grade									
	4	5	6	7	8	9	10	11	12	13
Lapping & Honing	■	■								
Cylindrical grinding		■	■	■						
Surface grinding		■	■	■	■					
Diamond turning		■	■	■						
Diamond boring		■	■	■						
Broaching		■	■	■	■					
Reaming			■	■	■	■	■			
Turning				■	■	■	■	■	■	■
Boring					■	■	■	■	■	■
Milling							■	■	■	■
Planing & Shaping							■	■	■	■
Drilling							■	■	■	■

Note: Adapted from ANSI B4.1–1967(R1999).