

Machinery's Handbook, 31st Edition

ERRATA (Selected Errors Found Since First Printing)

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| 375 | Page reference number (added) |
| 423-426 | Table subtitle |
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| 690 | Text correction |
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| 1022 | Figure label |
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| 1307 | Figure label |
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| 2023 | Equation correction |
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Acceleration is the time-rate of change of velocity and is expressed as velocity divided by time or as distance divided by time squared, that is, in feet per second per second or feet per second squared (ft/sec^2); inches per second per second or inches per second squared (in/sec^2); centimeters per second per second or centimeters per second squared (cm/sec^2); etc. **The metric SI unit is the meter per second squared (m/sec^2)**.

Unit Abbreviations.—Standard abbreviations for the units of physical quantities are used throughout the Handbook. Comprehensive tables of unit abbreviations are found starting on page 2827 for US units, and on page 2832 for metric units.

Unit Systems.—In mechanics calculations, both *absolute* and *gravitational* systems of units are employed. The fundamental quantities in absolute systems are *length*, *time*, and *mass*, and from these the dimension of *force* is derived. Two absolute systems that have been in use for many years are the CGS (centimeter-gram-second) and the MKS (meter-kilogram-second) systems. They are named for the fundamental units of length, mass and time, respectively. Another system known as MKSA (meter-kilogram-second-ampere) links the MKS system of units of mechanics with electromagnetic units.

The General Conference of Weights and Measures (CGPM), which is the body responsible for all international matters concerning the metric system, adopted in 1954 a rationalized and coherent system of units based on the four MKSA units, including the kelvin as the unit of temperature and the candela as the unit of luminous intensity. In 1960, the CGPM formally named this system the "Système International d'Unités," for which the abbreviation is SI in all languages. In 1971, the 14th CGPM adopted a seventh base unit, the *mole*, which is the unit of quantity ("amount of substance"). Further details of the SI are given in the section MEASURING UNITS starting on page 2831, and its application in mechanics calculations, contrasted with the use of the English system, is considered below.

The fundamental quantities in gravitational systems are *length*, *time*, and *force*, and from these units, the dimension of *mass* is derived. In the gravitational system most widely used in English measure countries, the units of length, time, and force are, respectively, the foot (ft), the second (s or sec), and the pound (lb). The corresponding unit of mass, commonly called the *slug*, is equal to $1 \text{ lb}\cdot\text{s}^2/\text{ft}$ and is derived from the formula, $M = W/g$ in which M = mass in slugs, W = weight in pounds, and g = acceleration due to gravity, commonly taken as 32.16 ft/s^2 . A body that weighs 32.16 lbs on the surface of the earth has, therefore, a mass of 1 slug.

Many engineering calculations utilize a system of units consisting of the inch, the second, and the pound. The corresponding units of mass are pounds second squared per inch ($\text{lb}\cdot\text{s}^2/\text{in}$) and the value of g is taken as 386 in/s^2 .

In a gravitational system that has been widely used in metric countries, the units of length, time, and force are, respectively, the meter, the second, and the kilogram-force ($1 \text{ kgf} = 9.80665 \text{ N}$). The corresponding units of mass are $\text{kgf}\cdot\text{s}^2/\text{m}$ and the value of g is taken as 9.81 m/s^2 .

Acceleration of Gravity g Used in Mechanics Formulas.—The acceleration of a freely falling body varies according to location on the earth's surface as well as the height from which the body falls. Its value measured at sea level at the equator is 32.09 ft/sec^2 while at the poles is 32.26 ft/sec^2 . In the United States it is customary to regard 32.16 as satisfactory for most practical purposes in engineering calculations.

Standard Pound Force: For use in defining the magnitude of a standard unit of force, known as the *pound force*, a fixed value of 32.1740 ft/sec^2 , designated by the symbol g_0 , has been adopted by international agreement. As a result of this agreement, whenever the term mass, M , appears in a mechanics formula and the substitution $M = W/g$ is made, use of the standard value $g_0 = 32.1740 \text{ ft/sec}^2$ is implied, although as stated previously, it is customary to use approximate values for g except where extreme accuracy is required.

Adjusting Lengths for Reference Temperature.—The standard reference temperature for industrial length measurements is 20 degrees Celsius (68 degrees Fahrenheit). For other temperatures, corrections should be made in accordance with the difference in thermal expansion for the two parts, especially when the gage is made of a different material than the part to be inspected.

Example: An aluminum part is to be measured with a steel gage when the room temperature is 30 °C. The aluminum part has a coefficient of linear thermal expansion, $\alpha_{Part} = 24.7 \times 10^{-6}$ mm/mm-°C, and for the steel gage, $\alpha_{Gage} = 10.8 \times 10^{-6}$ mm/mm-°C.

At the reference temperature, the specified length of the aluminum part is 20.021 mm. What is the length of the part at the measuring (room) temperature?

ΔL , the change in the measured length due to temperature, is given by:

$$\begin{aligned}\Delta L &= L(T_R - T_0)(\alpha_{Part} - \alpha_{Gage}) \\ &= 20.021(30 - 20)(24.7 - 10.8) \times 10^{-6} \text{ mm} \\ &= 2782.919 \times 10^{-6} \approx 0.003 \text{ mm}\end{aligned}$$

Page number 373 added
to cross references.



where L = length of part at reference temperature; T_R = room temperature (temperature of part and gage) and T_0 = reference temperature.

Thus, the temperature-corrected length at 30°C is $L + \Delta L = 20.021 + 0.003 = 20.024$ mm.

Length Change Due to Temperature.—Table 14 gives changes in length for variations from the standard reference temperature of 68°F (20°C) for materials of known coefficients of expansion, α . Coefficients of expansion are given in tables on pages 372, 373, 374, 386, 387, and elsewhere.

Example: In Table 14, for coefficients between those listed, add appropriate listed values. For example, a length change for a coefficient of 7 is the sum of values in the 5 and 2 columns. Fractional interpolation also is possible. Thus, in a steel bar with a coefficient of thermal expansion of $6.3 \times 10^{-6} = 0.0000063$ in/in = 6.3 $\mu\text{in}/\text{in}$ of length/°F, the increase in length at 73°F is $25 + 5 + 1.5 = 31.5 \mu\text{in}/\text{in}$ of length. For a steel with the same coefficient of expansion, the change in length, measured in degrees C, is expressed in microns (micrometers)/meter ($\mu\text{m}/\text{m}$) of length.

Alternatively, and for temperatures beyond the scope of the table, the length difference due to a temperature change is equal to the coefficient of expansion multiplied by the change in temperature, i.e., $\Delta L = \alpha \Delta T$. Thus, for the previous example, $\Delta L = 6.3 \times (73 - 68) = 6.3 \times 5 = 31.5 \mu\text{in}/\text{in}$.

Change in Radius of Thin Circular Ring with Temperature.—Consider a circular ring of initial radius r , that undergoes a temperature change ΔT . Initially, the circumference of the ring is $c = 2\pi r$. If the coefficient of expansion of the ring material is α , the change in circumference due to the temperature change is $\Delta c = 2\pi r \alpha \Delta T$.

The new circumference of the ring will be: $c_n = c + \Delta c = 2\pi r + 2\pi r \alpha \Delta T = 2\pi r(1 + \alpha \Delta T)$.

Note: An increase in temperature causes Δc to be positive, and a decrease in temperature causes Δc to be negative.

As the circumference increases, the radius of the circle also increases. If the new radius is R , the new circumference is $2\pi R$. For a given change in temperature, ΔT , the change in radius of the ring is found as follows:

$$c_n = 2\pi R = 2\pi r(1 + \alpha \Delta T) \quad R = r + r\alpha \Delta T \quad \Delta r = R - r = r\alpha \Delta T$$

Subtitle in parentheses of this table (MH31 pages 423-426) changed (from incorrect subtitle "Hot Rolled, Normalized, and Annealed")

MECHANICAL PROPERTIES OF STEELS

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Table 11b. Typical Mechanical Properties of Selected Carbon and Alloy Steels (Quenched-and-Tempered Condition)

| AISI No. ^a | Tempering Temperature, °F | Tensile Strength | | Elongation, Percent | Reduction in Area, Percent | Hardness, BHN |
|--------------------------|---------------------------------|-------------------------|-------|------------------------|----------------------------------|------------------|
| | | Ultimate | Yield | | | |
| | | 1000 lb/in ² | | | | |
| 1030 ^b | 400 | 123 | 94 | 17 | 47 | 495 |
| | 600 | 116 | 90 | 19 | 53 | 401 |
| | 800 | 106 | 84 | 23 | 60 | 302 |
| | 1000 | 97 | 75 | 28 | 65 | 255 |
| | 1200 | 85 | 64 | 32 | 70 | 207 |
| 1040 ^b | 400 | 130 | 96 | 16 | 45 | 514 |
| | 600 | 129 | 94 | 18 | 52 | 444 |
| | 800 | 122 | 92 | 21 | 57 | 352 |
| | 1000 | 113 | 86 | 23 | 61 | 269 |
| | 1200 | 97 | 72 | 28 | 68 | 201 |
| 1040 | 400 | 113 | 86 | 19 | 48 | 262 |
| | 600 | 113 | 86 | 20 | 53 | 255 |
| | 800 | 110 | 80 | 21 | 54 | 241 |
| | 1000 | 104 | 71 | 26 | 57 | 212 |
| | 1200 | 92 | 63 | 29 | 65 | 192 |
| 1050 ^b | 400 | 163 | 117 | 9 | 27 | 514 |
| | 600 | 158 | 115 | 13 | 36 | 444 |
| | 800 | 145 | 110 | 19 | 48 | 375 |
| | 1000 | 125 | 95 | 23 | 58 | 293 |
| | 1200 | 104 | 78 | 28 | 65 | 235 |
| 1050 | 400 | ... | ... | ... | ... | ... |
| | 600 | 142 | 105 | 14 | 47 | 321 |
| | 800 | 136 | 95 | 20 | 50 | 277 |
| | 1000 | 127 | 84 | 23 | 53 | 262 |
| | 1200 | 107 | 68 | 29 | 60 | 223 |
| 1060 | 400 | 160 | 113 | 13 | 40 | 321 |
| | 600 | 160 | 113 | 13 | 40 | 321 |
| | 800 | 156 | 111 | 14 | 41 | 311 |
| | 1000 | 140 | 97 | 17 | 45 | 277 |
| | 1200 | 116 | 76 | 23 | 54 | 229 |
| 1080 | 400 | 190 | 142 | 12 | 35 | 388 |
| | 600 | 189 | 142 | 12 | 35 | 388 |
| | 800 | 187 | 138 | 13 | 36 | 375 |
| | 1000 | 164 | 117 | 16 | 40 | 321 |
| | 1200 | 129 | 87 | 21 | 50 | 255 |
| 1095 ^b | 400 | 216 | 152 | 10 | 31 | 601 |
| | 600 | 212 | 150 | 11 | 33 | 534 |
| | 800 | 199 | 139 | 13 | 35 | 388 |
| | 1000 | 165 | 110 | 15 | 40 | 293 |
| | 1200 | 122 | 85 | 20 | 47 | 235 |
| 1095 | 400 | 187 | 120 | 10 | 30 | 401 |
| | 600 | 183 | 118 | 10 | 30 | 375 |
| | 800 | 176 | 112 | 12 | 32 | 363 |
| | 1000 | 158 | 98 | 15 | 37 | 321 |
| | 1200 | 130 | 80 | 21 | 47 | 269 |
| 1137 | 400 | 157 | 136 | 5 | 22 | 352 |
| | 600 | 143 | 122 | 10 | 33 | 285 |
| | 800 | 127 | 106 | 15 | 48 | 262 |
| | 1000 | 110 | 88 | 24 | 62 | 229 |
| | 1200 | 95 | 70 | 28 | 69 | 197 |

Table 11b. (Continued) Typical Mechanical Properties of Selected Carbon and Alloy Steels (Quenched-and-Tempered Condition)

| AISI No. ^a | Tempering Temperature, °F | Tensile Strength | | Elongation, Percent | Reduction in Area, Percent | Hardness, BHN |
|-----------------------|---------------------------|-------------------------|-------|---------------------|----------------------------|---------------|
| | | Ultimate | Yield | | | |
| | | 1000 lb/in ² | | | | |
| 1137 ^b | 400 | 217 | 169 | 5 | 17 | 415 |
| | 600 | 199 | 163 | 9 | 25 | 375 |
| | 800 | 160 | 143 | 14 | 40 | 311 |
| | 1000 | 120 | 105 | 19 | 60 | 262 |
| | 1200 | 94 | 77 | 25 | 69 | 187 |
| | 1141 | 237 | 176 | 6 | 17 | 461 |
| 1144 | 400 | 212 | 186 | 9 | 32 | 415 |
| | 600 | 169 | 150 | 12 | 47 | 331 |
| | 800 | 130 | 111 | 18 | 57 | 262 |
| | 1000 | 103 | 86 | 23 | 62 | 217 |
| | 1200 | 91 | 73 | 17 | 36 | 277 |
| | 1330 ^b | 236 | 211 | 9 | 39 | 459 |
| 1340 | 400 | 207 | 186 | 9 | 44 | 402 |
| | 600 | 168 | 150 | 15 | 53 | 335 |
| | 800 | 123 | 88 | 18 | 42 | 248 |
| | 1000 | 117 | 83 | 20 | 46 | 235 |
| | 1200 | 105 | 73 | 23 | 55 | 217 |
| | 4037 | 232 | 211 | 9 | 39 | 459 |
| 4042 | 400 | 262 | 231 | 11 | 35 | 505 |
| | 600 | 230 | 206 | 12 | 43 | 453 |
| | 800 | 183 | 167 | 14 | 51 | 375 |
| | 1000 | 140 | 120 | 17 | 58 | 295 |
| | 1200 | 116 | 90 | 22 | 66 | 252 |
| | 4130 ^b | 149 | 110 | 6 | 38 | 310 |
| 4140 | 400 | 138 | 111 | 14 | 53 | 295 |
| | 600 | 127 | 106 | 20 | 60 | 270 |
| | 800 | 115 | 95 | 23 | 63 | 247 |
| | 1000 | 101 | 61 | 29 | 60 | 220 |
| | 1200 | 261 | 241 | 12 | 37 | 516 |
| | 400 | 234 | 211 | 13 | 42 | 455 |
| 4150 | 600 | 187 | 170 | 15 | 51 | 380 |
| | 800 | 143 | 128 | 20 | 59 | 300 |
| | 1000 | 115 | 100 | 28 | 66 | 238 |
| | 1200 | 236 | 212 | 10 | 41 | 467 |
| | 400 | 217 | 200 | 11 | 43 | 435 |
| | 600 | 186 | 173 | 13 | 49 | 380 |
| 4340 | 800 | 150 | 132 | 17 | 57 | 315 |
| | 1000 | 118 | 102 | 22 | 64 | 245 |
| | 1200 | 257 | 238 | 8 | 38 | 510 |
| | 400 | 225 | 208 | 9 | 43 | 445 |
| | 600 | 181 | 165 | 13 | 49 | 370 |
| | 800 | 138 | 121 | 18 | 58 | 285 |
| | 1000 | 110 | 95 | 22 | 63 | 230 |
| | 400 | 280 | 250 | 10 | 39 | 530 |
| | 600 | 256 | 231 | 10 | 40 | 495 |
| | 800 | 220 | 200 | 12 | 45 | 440 |
| | 1000 | 175 | 160 | 15 | 52 | 370 |
| | 1200 | 139 | 122 | 19 | 60 | 290 |
| | 400 | 272 | 243 | 10 | 38 | 520 |
| | 600 | 250 | 230 | 10 | 40 | 486 |
| | 800 | 213 | 198 | 10 | 44 | 430 |
| | 1000 | 170 | 156 | 13 | 51 | 360 |
| | 1200 | 140 | 124 | 19 | 60 | 280 |

Table 11b. (Continued) Typical Mechanical Properties of Selected Carbon and Alloy Steels (Quenched-and-Tempered Condition)

| AISI No. ^a | Tempering Temperature, °F | Tensile Strength | | Elongation, Percent | Reduction in Area, Percent | Hardness, BHN |
|--------------------------|---------------------------------|-------------------------|-------|------------------------|----------------------------------|------------------|
| | | Ultimate | Yield | | | |
| | | 1000 lb/in ² | | | | |
| 5046 | 400 | 253 | 204 | 9 | 25 | 482 |
| | 600 | 205 | 168 | 10 | 37 | 401 |
| | 800 | 165 | 135 | 13 | 50 | 336 |
| | 1000 | 136 | 111 | 18 | 61 | 282 |
| | 1200 | 114 | 95 | 24 | 66 | 235 |
| | 400 | ... | ... | ... | ... | 560 |
| 50B46 | 600 | 258 | 235 | 10 | 37 | 505 |
| | 800 | 202 | 181 | 13 | 47 | 405 |
| | 1000 | 157 | 142 | 17 | 51 | 322 |
| | 1200 | 128 | 115 | 22 | 60 | 273 |
| | 400 | ... | ... | ... | ... | 600 |
| | 600 | 273 | 257 | 8 | 32 | 525 |
| 50B60 | 800 | 219 | 201 | 11 | 34 | 435 |
| | 1000 | 163 | 145 | 15 | 38 | 350 |
| | 1200 | 130 | 113 | 19 | 50 | 290 |
| | 400 | 234 | 220 | 10 | 40 | 475 |
| | 600 | 217 | 204 | 10 | 46 | 440 |
| | 800 | 185 | 175 | 12 | 51 | 379 |
| 5130 | 1000 | 150 | 136 | 15 | 56 | 305 |
| | 1200 | 115 | 100 | 20 | 63 | 245 |
| | 400 | 260 | 238 | 9 | 38 | 490 |
| | 600 | 229 | 210 | 10 | 43 | 450 |
| | 800 | 190 | 170 | 13 | 50 | 365 |
| | 1000 | 145 | 125 | 17 | 58 | 280 |
| 5140 | 1200 | 110 | 96 | 25 | 66 | 235 |
| | 400 | 282 | 251 | 5 | 37 | 525 |
| | 600 | 252 | 230 | 6 | 40 | 475 |
| | 800 | 210 | 190 | 9 | 47 | 410 |
| | 1000 | 163 | 150 | 15 | 54 | 340 |
| | 1200 | 117 | 118 | 20 | 60 | 270 |
| 5150 | 400 | 322 | 260 | 4 | 10 | 627 |
| | 600 | 290 | 257 | 9 | 30 | 555 |
| | 800 | 233 | 212 | 10 | 37 | 461 |
| | 1000 | 169 | 151 | 12 | 47 | 341 |
| | 1200 | 130 | 116 | 20 | 56 | 269 |
| | 400 | ... | ... | ... | ... | 600 |
| 51B60 | 600 | ... | ... | ... | ... | 540 |
| | 800 | 237 | 216 | 11 | 36 | 460 |
| | 1000 | 175 | 160 | 15 | 44 | 355 |
| | 1200 | 140 | 126 | 20 | 47 | 290 |
| | 400 | 280 | 245 | 8 | 38 | 538 |
| | 600 | 250 | 228 | 8 | 39 | 483 |
| 6150 | 800 | 208 | 193 | 10 | 43 | 420 |
| | 1000 | 168 | 155 | 13 | 50 | 345 |
| | 1200 | 137 | 122 | 17 | 58 | 282 |
| | 400 | 295 | 250 | 10 | 33 | 550 |
| | 600 | 256 | 228 | 8 | 42 | 475 |
| | 800 | 204 | 190 | 11 | 48 | 405 |
| 81B45 | 1000 | 160 | 149 | 16 | 53 | 338 |
| | 1200 | 130 | 115 | 20 | 55 | 280 |

Parenthetical subtitle corrected.

Table 11b. (Continued) Typical Mechanical Properties of Selected Carbon and Alloy Steels (Quenched-and-Tempered Condition)

| AISI No. ^a | Tempering Temperature, °F | Tensile Strength | | Elongation, Percent | Reduction in Area, Percent | Hardness, BHN |
|-----------------------|---------------------------|-------------------------|-------|---------------------|----------------------------|---------------|
| | | Ultimate | Yield | | | |
| | | 1000 lb/in ² | | | | |
| 8630 | 400 | 238 | 218 | 9 | 38 | 465 |
| | 600 | 215 | 202 | 10 | 42 | 430 |
| | 800 | 185 | 170 | 13 | 47 | 375 |
| | 1000 | 150 | 130 | 17 | 54 | 310 |
| | 1200 | 112 | 100 | 23 | 63 | 240 |
| 8640 | 400 | 270 | 242 | 10 | 40 | 505 |
| | 600 | 240 | 220 | 10 | 41 | 460 |
| | 800 | 200 | 188 | 12 | 45 | 400 |
| | 1000 | 160 | 150 | 16 | 54 | 340 |
| | 1200 | 130 | 116 | 20 | 62 | 280 |
| 86B45 | 400 | 287 | 238 | 9 | 31 | 525 |
| | 600 | 246 | 225 | 9 | 40 | 475 |
| | 800 | 200 | 191 | 11 | 41 | 395 |
| | 1000 | 160 | 150 | 15 | 49 | 335 |
| | 1200 | 131 | 127 | 19 | 58 | 280 |
| 8650 | 400 | 281 | 243 | 10 | 38 | 525 |
| | 600 | 250 | 225 | 10 | 40 | 490 |
| | 800 | 210 | 192 | 12 | 45 | 420 |
| | 1000 | 170 | 153 | 15 | 51 | 340 |
| | 1200 | 140 | 120 | 20 | 58 | 280 |
| 8660 | 400 | ... | ... | ... | ... | 580 |
| | 600 | ... | ... | ... | ... | 535 |
| | 800 | 237 | 225 | 13 | 37 | 460 |
| | 1000 | 190 | 176 | 17 | 46 | 370 |
| | 1200 | 155 | 138 | 20 | 53 | 315 |
| 8740 | 400 | 290 | 240 | 10 | 41 | 578 |
| | 600 | 249 | 225 | 11 | 46 | 495 |
| | 800 | 208 | 197 | 13 | 50 | 415 |
| | 1000 | 175 | 165 | 15 | 55 | 363 |
| | 1200 | 143 | 131 | 20 | 60 | 302 |
| 9255 | 400 | 305 | 297 | 1 | 3 | 601 |
| | 600 | 281 | 260 | 4 | 10 | 578 |
| | 800 | 233 | 216 | 8 | 22 | 477 |
| | 1000 | 182 | 160 | 15 | 32 | 352 |
| | 1200 | 144 | 118 | 20 | 42 | 285 |
| 9260 | 400 | ... | ... | ... | ... | 600 |
| | 600 | ... | ... | ... | ... | 540 |
| | 800 | 255 | 218 | 8 | 24 | 470 |
| | 1000 | 192 | 164 | 12 | 30 | 390 |
| | 1200 | 142 | 118 | 20 | 43 | 295 |
| 94B30 | 400 | 250 | 225 | 12 | 46 | 475 |
| | 600 | 232 | 206 | 12 | 49 | 445 |
| | 800 | 195 | 175 | 13 | 57 | 382 |
| | 1000 | 145 | 135 | 16 | 65 | 307 |
| | 1200 | 120 | 105 | 21 | 69 | 250 |

^aAll grades are fine-grained except those in the 1100 series that are coarse-grained. Austenitizing temperatures are given in parentheses. Heat-treated specimens were oil-quenched unless otherwise indicated.

^bWater quenched.

Source: Bethlehem Steel Corp. and Republic Steel Corp. as published in 1974 DATABOOK issue of the American Society for Metals' *Metal Progress* magazine and used with permission.

Selecting metals with similar electrochemical potentials usually minimizes galvanic corrosion. One method of comparing potentials involves referencing a *galvanic series*. While it should be representative of anticipated environmental conditions, this tool is not used to predict corrosion rates, but rather provides a qualitative evaluation of coupled metal behavior.

To develop a series, a reference half-cell and samples of the target metals are immersed together in an electrolyte solution chosen and circulated to match the expected environmental conditions. Over time, potentials of the target metals are measured relative to the reference half-cell. There are several standard reference half-cell compositions that will yield different values; the appropriate reference is compatible with the electrolyte. A useful standard is ASTM G82-98 (2014), “Standard Guide for Development and Use of a Galvanic Series for Predicting Galvanic Corrosion Performance.”

Most published galvanic series data applies to specific flowing seawater environment conditions. While saltwater is highly conductive, freshwater has low conductivity, and dynamic electrolyte conditions will greatly affect potential measurements. Therefore, for critical applications, it is good practice to develop application-specific series data, rather than using published galvanic series information.

For examples of seawater applications, refer to Table 2, which is based on Army Missile Command Report RS-TR-67-11, “Practical Galvanic Series.” Materials closer together along the arrow in the series have less corrosion-inducing potential difference between them in that environment. However, use this data with caution in predicting whether corrosion will be a risk. This series indicates which material will be the anode in a couple, though polarity reversals can occur in which a metal normally anodic to another will become cathodic to that same metal. Examples include high-temperature reversals of zinc/iron, aluminum/iron, and aluminum/zinc.

Table 2. Sample Galvanic Series, General Seawater Environment

| Active (Anodic) | Noble (Cathodic) |
|--|---|
| Magnesium Mg alloy AZ-31B Mg alloy HK-31A Zinc (hot-dip, die cast, or plated) Beryllium (hot-pressed) Aluminum 7072 clad on 7075 Aluminum 2014-T3 Aluminum 1160-H14 Aluminum 7079-T6 Cadmium (plated) Uranium Aluminum 218 (die cast) Aluminum 5052-0 Aluminum 5052-H12 Aluminum 5456-0, H353 Aluminum 5052-H32 Aluminum 1100-0 Aluminum 3003-H25 Aluminum 6061-T6 Aluminum A360 (die cast) Aluminum 7075-T6 Aluminum 6061-0 Indium Aluminum 2014-0 Aluminum 2024-T4 Aluminum 5052-H16 Tin (plated) Stainless Steel 430 (active) Lead Steel 1010 Iron (cast) | Stainless Steel 410 (active) Copper (plated, cast, or wrought) Nickel (plated) Chromium (plated) Tantalum AM350 (active) Stainless Steel 310 (active) Stainless Steel 301 (active) Stainless Steel 304 (active) Stainless Steel 430 (active) Stainless Steel 410 (active) Stainless Steel 17-7PH (active) Tungsten Niobium (columbium) 1% Zr Brass, Yellow, 268 Uranium 8% Mo Brass, Naval, 464 Yellow Brass Muntz Metal 280 Brass (plated) Nickel-Silver (18% Ni) Stainless Steel 316L (active) Bronze 220 Copper 110 Red Brass Stainless Steel 347 (active) Molybdenum (commercial pure) Copper-Nickel 715 Admiralty Brass Stainless Steel 202 (active) Bronze, Phosphor 534 (B-1) Monel 400 |

Name corrected
(was
"Silicone
Bronze 655"
so "e"
removed)

Multiple changes made to these 2 tables,
particularly to Metric conversions.

Table 2a. Typical Mechanical Properties of Common Plastics (Inch)

| Material | Yield Stress, ksi | | | Elastic Modulus, ksi | | | Heat Deflection Temperature, °F | | | Izod Impact Strength, ft/lb/in | | |
|--------------|-------------------|--------|---------|----------------------|---------|---------|---------------------------------|--------|---------|--------------------------------|--------|---------|
| | Minimum | Median | Maximum | Minimum | Median | Maximum | Minimum | Median | Maximum | Minimum | Median | Maximum |
| ABS | 2.9 | 6.3 | 10.7 | 112.8 | 333.5 | 884.5 | 149 | 192 | 244 | 0.19 | 4.12 | 12 |
| PC | 5.8 | 9.1 | 22.3 | 261 | 346.55 | 870 | 172 | 261 | 369 | 0.84 | 16.7 | 37.4 |
| PEEK | 9.425 | 14.1 | 16.7 | 319 | 568.4 | 939.6 | 284 | 316 | 500 | 0.39 | 1.09 | 3.18 |
| PET | 0.3045 | 5.6 | 13.1 | 130.5 | 456.75 | 754 | 140 | 159 | 239 | 0.26 | 1.12 | 1.55 |
| PP | 1.2992 | 3.6 | 5.1 | 108.8 | 195.75 | 507.5 | 100 | 135 | 239 | 0.5 | 4.02 | 13.5 |
| PP, GF | 3.625 | 8.7 | 13.1 | 149.4 | 609 | 949.75 | 140 | 268 | 374 | 0.26 | 1.8 | 8.42 |
| PE, HD | 1.102 | 3.1 | 6.2 | 65.3 | 134.415 | 217.5 | 100 | 118 | 187 | 0.36 | 1.44 | 37.4 |
| PE, LD | 1.1165 | 1.6 | 9.4 | 16 | 33.64 | 65.105 | 100 | 153 | 214 | 4.49 | 8.42 | 37.4 |
| PMMA | 3.625 | 9.3 | 12.3 | 137.8 | 420.5 | 549.55 | 125 | 193 | 223 | 0.22 | 0.56 | 2.75 |
| PSU | 6.96 | 12.8 | 26.8 | 249.4 | 817.8 | 2798.5 | 175 | 352 | 500 | 0.5 | 1.42 | 7.86 |
| PVC | 0.2315 | 2.4 | 8.6 | 0.2 | 313.2 | 469.8 | 116 | 159 | 189 | 0.39 | 11.6 | 37.4 |
| TS Phenolic | 5.945 | 7.7 | 8.4 | 594.5 | 1015 | 1252.8 | 320 | 349 | 439 | 0.39 | 0.51 | 0.6 |
| TS Epoxy | 0.10005 | 3.3 | 12.3 | 14.5 | 359.6 | 870 | 149 | 295 | 649 | 0.36 | 0.67 | 1.29 |
| TS Epoxy, GF | 12.035 | 16.5 | 21.8 | 435 | 2088 | 2755 | 329 | 439 | 536 | 0.3 | 0.54 | 0.69 |
| TS Polyester | 1.45 | 7.5 | 17.8 | 145 | 584.35 | 1537 | 392 | 486 | 500 | 2.3 | 7.49 | 17 |
| TS Polyimide | 10.585 | 18.6 | 23.2 | 159.5 | 569.85 | 1566 | 356 | 707 | 752 | 0.39 | 0.66 | 0.8 |

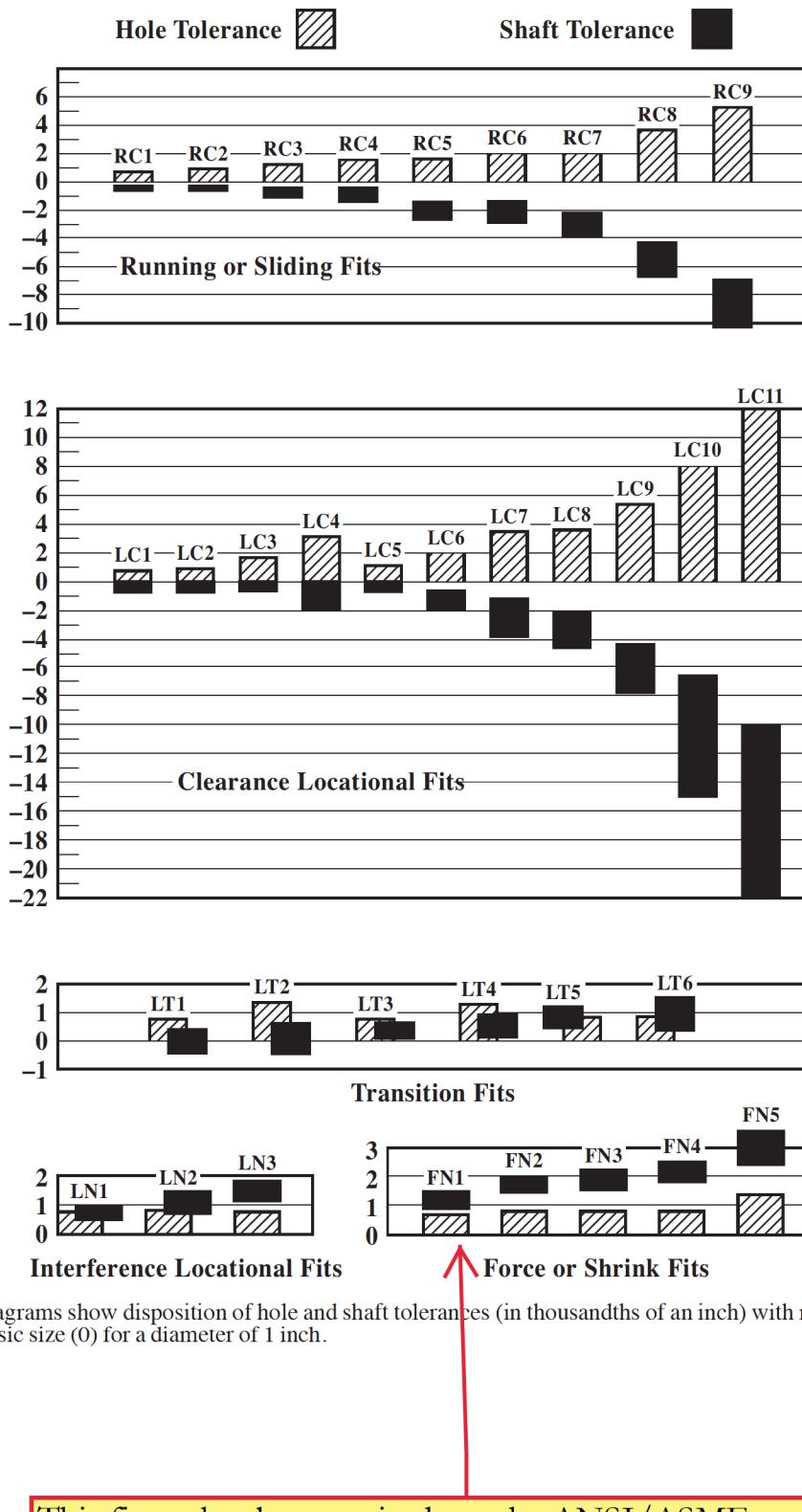
Table 2b. Typical Mechanical Properties of Common Plastics (Metric)

| Material | Yield Stress, MPa | | | Elastic Modulus, GPa | | | Heat Deflection Temperature, °C | | | Izod Impact Strength, J/cm | | |
|--------------|-------------------|--------|---------|----------------------|--------|---------|---------------------------------|--------|---------|----------------------------|--------|---------|
| | Minimum | Median | Maximum | Minimum | Median | Maximum | Minimum | Median | Maximum | Minimum | Median | Maximum |
| ABS | 20 | 43.4 | 73.5 | 0.778 | 2.3 | 6.1 | 65 | 88.9 | 118 | 0.1 | 2.2 | 6.4 |
| PC | 40 | 62.7 | 154 | 1.8 | 2.39 | 6 | 77.8 | 127 | 187 | 0.45 | 8.92 | 20 |
| PEEK | 65 | 97.4 | 115 | 2.2 | 3.92 | 6.48 | 140 | 158 | 260 | 0.21 | 0.58 | 1.7 |
| PET | 2.1 | 38.8 | 90 | 0.9 | 3.15 | 5.2 | 60 | 70.3 | 115 | 0.139 | 0.6 | 0.83 |
| PP | 8.96 | 25 | 35.2 | 0.75 | 1.35 | 3.5 | 37.8 | 57 | 115 | 0.267 | 2.15 | 7.2 |
| PP, GF | 25 | 60 | 90 | 1.03 | 4.2 | 6.55 | 60 | 131 | 190 | 0.14 | 0.96 | 4.5 |
| PE, HD | 7.6 | 21.3 | 43 | 0.45 | 0.927 | 1.5 | 37.6 | 47.5 | 86.1 | 0.19 | 0.77 | 20 |
| PE, LD | 7.7 | 10.8 | 64.8 | 0.11 | 0.232 | 0.449 | 38 | 67.4 | 101 | 2.4 | 4.5 | 20 |
| PMMA | 25 | 64 | 85 | 0.95 | 2.9 | 3.79 | 51.7 | 89.4 | 106 | 0.12 | 0.3 | 1.47 |
| PSU | 48 | 88.1 | 185 | 1.72 | 5.64 | 19.3 | 79.4 | 178 | 260 | 0.267 | 0.76 | 4.2 |
| PVC | 1.47 | 16.4 | 59 | 0.0016 | 2.16 | 3.24 | 46.7 | 70.8 | 87.2 | 0.21 | 6.2 | 20 |
| TS Phenolic | 41 | 53.2 | 57.9 | 4.1 | 7 | 8.64 | 160 | 176 | 226 | 0.21 | 0.27 | 0.32 |
| TS Epoxy | 0.69 | 22.8 | 85.1 | 0.1 | 2.48 | 6 | 65 | 146 | 343 | 0.19 | 0.36 | 0.69 |
| TS Epoxy, GF | 83 | 114 | 150 | 3 | 14.4 | 19 | 165 | 226 | 280 | 0.16 | 0.29 | 0.37 |
| TS Polyester | 10 | 51.8 | 123 | 1 | 4.03 | 10.6 | 200 | 252 | 260 | 1.23 | 4 | 9.08 |
| TS Polyimide | 73 | 128 | 160 | 1.1 | 3.93 | 10.8 | 180 | 375 | 400 | 0.21 | 0.35 | 0.43 |

Statistical summary of available grades submitted by material suppliers (data courtesy of MatWeb.com).

The limits for hole and shaft as given in Table 8a to Table 12 are increased for clearance fits (*decreased* for transition or interference fits) by the value of the upper shaft limit, that is, by the amount required to change the maximum shaft to the basic size.

Graphical Representation of ANSI/ASME Standard Limits and Fits
ANSI/ASME B4.1-1967 (2009; out of print)



Change to:
(R2020)

Table 9b. American National Standard Clearance Locational Fits ANSI/ASME B4.1-1967(2009, out of print)

| Nominal Size Range, Inches | Clearance ^a | Class LC 6 | | Class LC 7 | | Class LC 8 | | Class LC 9 | | Class LC 10 | | Class LC 11 | | | | | | |
|--|------------------------|------------|----------|-----------------------|----------|-----------------------|----------|-----------------------|-------------|-----------------------|-----------|-----------------------|----------|-------|------|-----|-----|-----|
| | | Hole H9 | Shaft f8 | Std. Tolerance Limits | | Std. Tolerance Limits | | Std. Tolerance Limits | | Std. Tolerance Limits | | Std. Tolerance Limits | | | | | | |
| | | | | Hole H10 | Shaft e9 | Clearance a | Hole H10 | Shaft d9 | Clearance a | Hole H11 | Shaft c10 | Clearance a | Hole H12 | Shaft | | | | |
| Values shown below are in thousandths of an inch | | | | | | | | | | | | | | | | | | |
| 0 - 0.12 | 0.3 | +1.0 | -0.3 | 0.6 | +1.6 | -0.6 | 1.0 | +1.6 | -1.0 | 2.5 | +2.5 | -2.5 | 4 | +4 | -4 | 5 | +6 | -5 |
| | 1.9 | 0 | -0.9 | 3.2 | 0 | -1.6 | 2.0 | 0 | -2.0 | 6.6 | 0 | -4.1 | 12 | 0 | -8 | 17 | 0 | -11 |
| 0.12 - 0.24 | 0.4 | +1.2 | -0.4 | 0.8 | +1.8 | -0.8 | 1.2 | +1.8 | -1.2 | 2.8 | +3.0 | -2.8 | 4.5 | +5 | -4.5 | 6 | +7 | -6 |
| | 2.3 | 0 | -1.1 | 3.8 | 0 | -2.0 | 4.2 | 0 | -2.4 | 7.6 | 0 | -4.6 | 14.5 | 0 | -9.5 | 20 | 0 | -13 |
| 0.24 - 0.40 | 0.5 | +1.4 | -0.5 | 1.0 | +2.2 | -1.0 | 1.6 | +2.2 | -1.6 | 3.0 | +3.5 | -3.0 | 5 | +6 | -5 | 7 | +9 | -7 |
| | 2.8 | 0 | -1.4 | 4.6 | 0 | -2.4 | 5.2 | 0 | -3.0 | 8.7 | 0 | -5.2 | 17 | 0 | -11 | 25 | 0 | -16 |
| 0.40 - 0.71 | 0.6 | +1.6 | -0.6 | 1.2 | +2.8 | -1.2 | 2.0 | +2.8 | -2.0 | 3.5 | +4.0 | -3.5 | 6 | +7 | -6 | 8 | +10 | -8 |
| | 3.2 | 0 | -1.6 | 5.6 | 0 | -2.8 | 6.4 | 0 | -3.6 | 10.3 | 0 | -6.3 | 20 | 0 | -13 | 28 | 0 | -18 |
| 0.71 - 1.19 | 0.8 | +2.0 | -0.8 | 1.6 | +3.5 | -1.6 | 2.5 | +3.5 | -2.5 | 4.5 | +5.0 | -4.5 | 7 | +8 | -7 | 10 | +12 | -10 |
| | 4.0 | 0 | -2.0 | 7.1 | 0 | -3.6 | 8.0 | 0 | -4.5 | 13.0 | 0 | -8.0 | 23 | 0 | -15 | 34 | 0 | -22 |
| 1.19 - 1.97 | 1.0 | +2.5 | -1.0 | 2.0 | +4.0 | -2.0 | 3.6 | +4.0 | -3.0 | 5.0 | +6 | -5.0 | 8 | +10 | -8 | 12 | +16 | -12 |
| | 5.1 | 0 | -2.6 | 8.5 | 0 | -4.5 | 9.5 | 0 | -5.5 | 15.0 | 0 | -9.0 | 28 | 0 | -18 | 44 | 0 | -28 |
| 1.97 - 3.15 | 1.2 | +3.0 | -1.0 | 2.5 | +4.5 | -2.5 | 4.0 | +4.5 | -4.0 | 6.0 | +7 | -6.0 | 10 | +12 | -10 | 14 | +18 | -14 |
| | 6.0 | 0 | -3.6 | 10.0 | 0 | -5.5 | 11.5 | 0 | -7.0 | 17.5 | 0 | -10.5 | 34 | 0 | -22 | 50 | 0 | -32 |
| 3.15 - 4.73 | 1.4 | +3.5 | -1.4 | 3.0 | +5.0 | -3.0 | 5.0 | +5.0 | -5.0 | 7 | +9 | -7 | 11 | +14 | -11 | 16 | +22 | -16 |
| | 7.1 | 0 | -3.6 | 11.5 | 0 | -6.5 | 13.5 | 0 | -8.5 | 21 | 0 | -12 | 39 | 0 | -25 | 60 | 0 | -38 |
| 4.73 - 7.09 | 1.6 | +4.0 | -1.6 | 3.5 | +6.0 | -3.5 | 6 | +6 | -6 | 8 | +10 | -8 | 12 | +16 | -12 | 18 | +25 | -18 |
| | 8.1 | 0 | -4.1 | 13.5 | 0 | -7.5 | 16 | 0 | -10 | 24 | 0 | -14 | 44 | 0 | -28 | 68 | 0 | -43 |
| 7.09 - 9.85 | 2.0 | +4.5 | -2.0 | 4.0 | +7.0 | -4.0 | 7 | +7 | -7 | 10 | +12 | -10 | 16 | +18 | -16 | 22 | +28 | -22 |
| | 9.3 | 0 | -4.8 | 15.5 | 0 | -8.5 | 18.5 | 0 | -11.5 | 29 | 0 | -17 | 52 | 0 | -34 | 78 | 0 | -50 |
| 9.85 - 12.41 | 2.2 | +5.0 | -2.2 | 4.5 | +8.0 | -4.5 | 7 | +8 | -7 | 12 | +12 | -12 | 20 | +20 | -20 | 28 | +30 | -28 |
| | 10.2 | 0 | -5.2 | 17.5 | 0 | -9.5 | 20 | 0 | -12 | 32 | 0 | -20 | 60 | 0 | -40 | 88 | 0 | -58 |
| 12.41 - 15.75 | 2.5 | +6.0 | -2.5 | 5.0 | +9.0 | -5 | 8 | +9 | -8 | 14 | +14 | -14 | 22 | +22 | -22 | 30 | +35 | -30 |
| | 12.0 | 0 | -6.0 | 20.0 | 0 | -11 | 23 | 0 | -14 | 37 | 0 | -23 | 66 | 0 | -44 | 100 | 0 | -65 |
| 15.75- 19.69 | 2.8 | +6.0 | -2.8 | 5.0 | +10.0 | -5 | 9 | +10 | -9 | 16 | +16 | -16 | 25 | +25 | -25 | 35 | +40 | -35 |
| | 12.8 | 0 | -6.8 | 20.0 | 0 | -11 | 25 | 0 | -15 | 42 | 0 | -26 | 75 | 0 | -50 | 115 | 0 | -75 |

^a Pairs of values shown represent minimum and maximum amounts of interference resulting from application of standard tolerance limits.

Limits for sizes above 19.69 inches are not covered by American-British-Canadian (ABC) agreements but are given in the ANSI/ASME Standard.

Change to: -1.2

MEASURING, INSTRUMENTS, AND INSPECTION METHODS

Reading Verniers and Micrometers

Reading a Vernier.—A general rule for taking readings with a vernier scale is as follows: Note the number of inches and subdivisions of an inch that the zero mark of the vernier scale has moved along the true scale, and then add to this reading as many thousandths, hundredths, or whatever fractional part of an inch the vernier reads to, as there are spaces between the vernier zero and that line on the vernier coinciding with one on the true scale. For example, if the zero line of a vernier that reads to thousandths is slightly beyond the 0.5 inch division on the main or true scale, as shown in Fig. 1, and graduation line 10 on the vernier exactly coincides with one on the true scale, the reading is $0.5 + 0.010$ or 0.510 inch. In order to determine the reading or fractional part of an inch that can be obtained by a vernier, multiply the denominator of the finest subdivision given on the true scale by the total number of divisions on the vernier. For example, if one inch on the true scale is divided into 40 parts or fortyths (as in Fig. 1), and the vernier into twenty-five parts, the vernier will read to thousandths of an inch, as $25 \times 40 = 1000$. Similarly, if there are sixteen divisions to the inch on the true scale and a total of eight on the vernier, the latter will enable readings to be taken within $\frac{1}{128}$ of an inch, as $8 \times 16 = 128$.

Fig. 1, and graduation line 8 on the vernier exactly coincides with one on the true scale, the reading is $0.5 + 0.008$ or 0.508 inch.

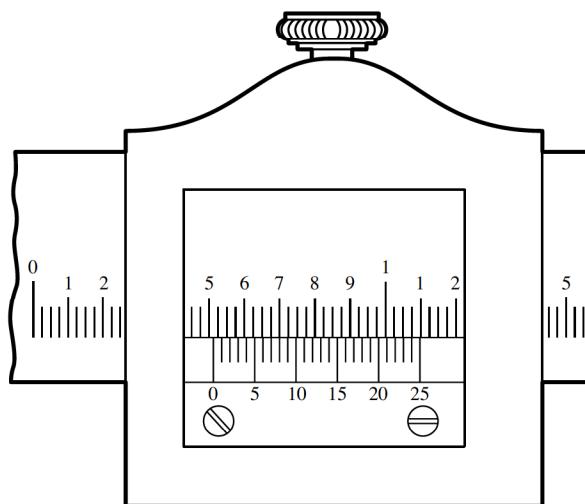


Fig. 1. Inch Vernier

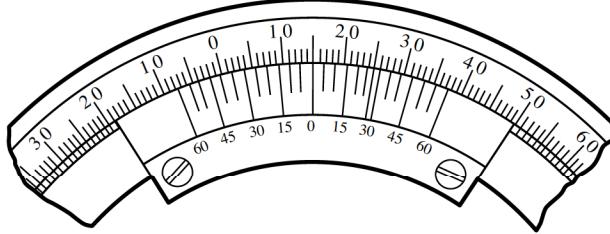


Fig. 2. Protractor with Vernier Scale

If the vernier is on a protractor, note the whole number of degrees passed by the vernier zero mark and then count the spaces between the vernier zero and the line coinciding with a graduation on the protractor scale. If the vernier indicates angles within five minutes or one-twelfth degree (as in Fig. 2), the number of spaces multiplied by 5 will, of course, give the number of minutes to be added to the whole number of degrees. The reading of the protractor set as illustrated would be 14 whole degrees (the number passed by the zero mark on the vernier) plus 30 minutes, as the graduation 30 on the vernier is the only one to the right of the vernier zero that exactly coincides with a line on the protractor scale. It will be

Table 1a. Morse Stub Taper Shanks

| No. of Taper | Taper per Foot ^a | Taper per Inch ^b | Small End of Plug, ^b <i>D</i> | Dia. End of Socket, ^a <i>A</i> | Shank | | Tang | |
|--------------------|-----------------------------------|-----------------------------------|---|--|------------------------------|--|------------------------|---------------------|
| | | | | | Total Length, <i>B</i> | Depth, <i>C</i> | Thickness, <i>E</i> | Length, <i>F</i> |
| 1 | 0.59858 | 0.049882 | 0.4314 | 0.475 | 1 5/16 | 1 1/8 | 13/64 | 5/16 |
| 2 | 0.59941 | 0.049951 | 0.6469 | 0.700 | 1 11/16 | 1 7/16 | 19/64 | 7/16 |
| 3 | 0.60235 | 0.050196 | 0.8753 | 0.938 | 2 | 1 3/4 | 25/64 | 9/16 |
| 4 | 0.62326 | 0.051938 | 1.1563 | 1.231 | 2 3/8 | 2 1/16 | 33/64 | 11/16 |
| 5 | 0.63151 | 0.052626 | 1.6526 | 1.748 | 3 | 2 11/16 | 3/4 | 15/16 |
| No. of Taper | Tang | | Socket | | | Tang Slot | | |
| | Radius of Mill, <i>G</i> | Diameter, <i>H</i> | Plug Depth, <i>P</i> | Min. Depth of Tapered Hole | | Socket End to Tang Slot, <i>M</i> | Width, <i>N</i> | Length, <i>O</i> |
| 1 | 3/16 | 13/32 | 7/8 | 15/16 | 29/32 | 25/32 | 7/32 | 23/32 |
| 2 | 7/32 | 39/64 | 11/16 | 15/32 | 17/64 | 15/16 | 5/16 | 15/16 |
| 3 | 9/32 | 13/16 | 1 1/4 | 13/8 | 15/16 | 11/16 | 13/32 | 1 1/8 |
| 4 | 3/8 | 13/32 | 1 7/16 | 1 9/16 | 1 1/2 | 13/16 | 17/32 | 1 3/8 |
| 5 | 9/16 | 119/32 | 113/16 | 1 15/16 | 17/8 | 17/16 | 25/32 | 1 3/4 |

All dimensions in inches.

Radius *J* is $\frac{3}{64}$, $\frac{1}{16}$, $\frac{5}{64}$, $\frac{3}{32}$, and $\frac{1}{8}$ inch respectively for Nos. 1, 2, 3, 4, and 5 tapers.

^a These are basic dimensions.^b These dimensions are calculated for reference only.

Corrected to 15/16
(was incorrectly 5/16)

Jarno Taper.—The Jarno taper was originally proposed by Oscar J. Beale of the Brown & Sharpe Mfg. Co. This taper is based on such simple formulas that practically no calculations are required when the number of taper is known. The taper per foot of all Jarno taper sizes is 0.600 inch on the diameter. The diameter at the large end is as many eighths, the diameter at the small end is as many tenths, and the length as many half inches as are indicated by the number of the taper. For example, a No. 7 Jarno taper is $\frac{7}{8}$ inch in diameter at the large end; $\frac{7}{10}$, or 0.700 inch at the small end; and $\frac{7}{2}$, or $3\frac{1}{2}$ inches long; hence, diameter at large end = No. of taper \div 8; diameter at small end = No. of taper \div 10; length of taper = No. of taper \div 2. The Jarno taper is used on various machine tools, especially profiling machines and die-sinking machines. It has also been used for the headstock and tailstock spindles of some lathes.

Letter in figure corrected to **H**
(was incorrectly **B**).

Table 8. Dimensions of Morse Taper Sleeves

A = No. Morse Taper Outside

| A | B | C | D | E | F | G | H | I | K | L | M |
|---|---|--------|-------|------|-------|------|-------|-------|--------|-------|-------|
| 2 | 1 | 39/16 | 0.700 | 5/8 | 1/4 | 7/16 | 23/16 | 0.475 | 21/16 | 3/4 | 0.213 |
| 3 | 1 | 315/16 | 0.938 | 1/4 | 5/16 | 9/16 | 23/16 | 0.475 | 21/16 | 3/4 | 0.213 |
| 3 | 2 | 47/16 | 0.938 | 3/4 | 5/16 | 9/16 | 25/8 | 0.700 | 21/2 | 7/8 | 0.260 |
| 4 | 1 | 47/8 | 1.231 | 1/4 | 15/32 | 5/8 | 23/16 | 0.475 | 21/16 | 3/4 | 0.213 |
| 4 | 2 | 47/8 | 1.231 | 1/4 | 15/32 | 5/8 | 25/8 | 0.700 | 21/2 | 7/8 | 0.260 |
| 4 | 3 | 53/8 | 1.231 | 3/4 | 15/32 | 5/8 | 31/4 | 0.938 | 31/16 | 13/16 | 0.322 |
| 5 | 1 | 61/8 | 1.748 | 1/4 | 5/8 | 3/4 | 23/16 | 0.475 | 21/16 | 3/4 | 0.213 |
| 5 | 2 | 61/8 | 1.748 | 1/4 | 5/8 | 3/4 | 25/8 | 0.700 | 21/2 | 7/8 | 0.260 |
| 5 | 3 | 61/8 | 1.748 | 1/4 | 5/8 | 3/4 | 31/4 | 0.938 | 31/16 | 13/16 | 0.322 |
| 5 | 4 | 65/8 | 1.748 | 3/4 | 5/8 | 3/4 | 41/8 | 1.231 | 37/8 | 11/4 | 0.478 |
| 6 | 1 | 85/8 | 2.494 | 3/8 | 3/4 | 11/8 | 23/16 | 0.475 | 21/16 | 3/4 | 0.213 |
| 6 | 2 | 85/8 | 2.494 | 3/8 | 3/4 | 11/8 | 25/8 | 0.700 | 21/2 | 7/8 | 0.260 |
| 6 | 3 | 85/8 | 2.494 | 3/8 | 3/4 | 11/8 | 31/4 | 0.938 | 31/16 | 13/16 | 0.322 |
| 6 | 4 | 85/8 | 2.494 | 3/8 | 3/4 | 11/8 | 41/8 | 1.231 | 37/8 | 11/4 | 0.478 |
| 6 | 5 | 85/8 | 2.494 | 3/8 | 3/4 | 11/8 | 51/4 | 1.748 | 415/16 | 11/2 | 0.635 |
| 7 | 3 | 115/8 | 3.270 | 3/8 | 11/8 | 13/8 | 31/4 | 0.938 | 31/16 | 13/16 | 0.322 |
| 7 | 4 | 115/8 | 3.270 | 3/8 | 11/8 | 13/8 | 41/8 | 1.231 | 37/8 | 11/4 | 0.478 |
| 7 | 5 | 115/8 | 3.270 | 3/8 | 11/8 | 13/8 | 51/4 | 1.748 | 415/16 | 11/2 | 0.635 |
| 7 | 6 | 121/2 | 3.270 | 11/4 | 11/8 | 13/8 | 73/8 | 2.494 | 7 | 13/4 | 0.760 |

Table 9. Morse Taper Sockets — Hole and Shank Sizes

| Size | Morse Taper | | Size | Morse Taper | | Size | Morse Taper | |
|--------|-------------|-------|--------|-------------|-------|--------|-------------|-------|
| | Hole | Shank | | Hole | Shank | | Hole | Shank |
| 1 by 2 | No. 1 | No. 2 | 2 by 5 | No. 2 | No. 5 | 4 by 4 | No. 4 | No. 4 |
| 1 by 3 | No. 1 | No. 3 | 3 by 2 | No. 3 | No. 2 | 4 by 5 | No. 4 | No. 5 |
| 1 by 4 | No. 1 | No. 4 | 3 by 3 | No. 3 | No. 3 | 4 by 6 | No. 4 | No. 6 |
| 1 by 5 | No. 1 | No. 5 | 3 by 4 | No. 3 | No. 4 | 5 by 4 | No. 5 | No. 4 |
| 2 by 3 | No. 2 | No. 3 | 3 by 5 | No. 3 | No. 5 | 5 by 5 | No. 5 | No. 5 |
| 2 by 4 | No. 2 | No. 4 | 4 by 3 | No. 4 | No. 3 | 5 by 6 | No. 5 | No. 6 |

Diamond Wheels

Diamond Wheels.—A diamond wheel is a special type of grinding wheel in which the abrasive elements are diamond grains held in a bond and applied to form a layer on the operating face of a non-abrasive core. Diamond wheels are used for grinding very hard or highly abrasive materials. Primary applications are the grinding of cemented carbides, such as the sharpening of carbide cutting tools; the grinding of glass, ceramics, asbestos, and cement products; and the cutting and slicing of germanium and silicon.

Shapes of Diamond Wheels.—The industry-wide accepted Standard (ANSIB74.3-2003 (R2014) specifies ten basic diamond wheel core shapes which are shown in Table 1 with the applicable designation symbols. The applied diamond abrasive layer may have different cross-sectional shapes. Those standardized are shown in Table 2. The third aspect which is standardized is the location of the diamond section on the wheel as shown by the diagrams in Table 3. Finally, modifications of the general core shape together with pertinent designation letters are given in Table 4.

The characteristics of the wheel shape listed in these four tables make up the components of the standard designation symbol for diamond wheel shapes. An example of that symbol with arbitrarily selected components is shown in Fig. 1.

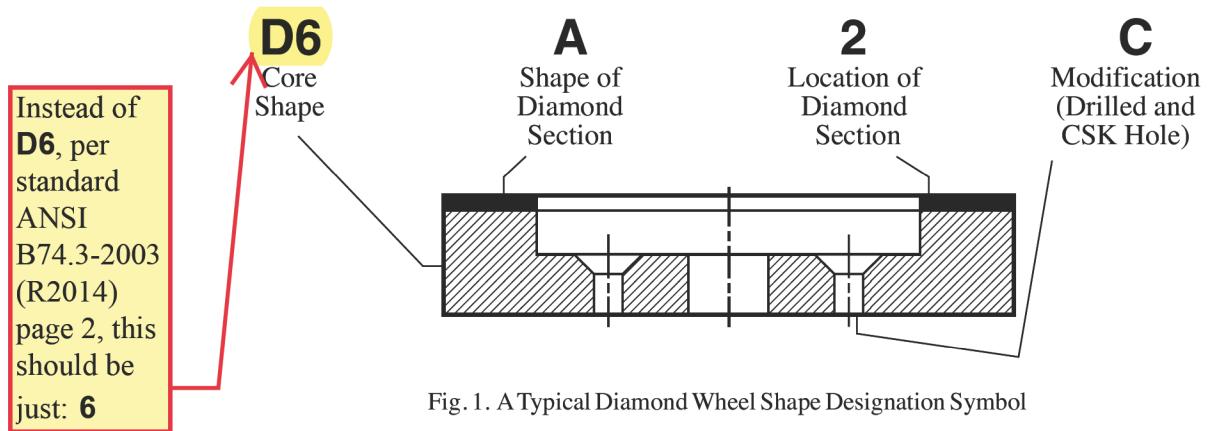


Fig. 1. A Typical Diamond Wheel Shape Designation Symbol

An explanation of these components is as follows:

Basic Core Shape: This portion of the symbol indicates the basic shape of the core on which the diamond abrasive section is mounted. The shape is actually designated by a number. The various core shapes and their designations are given in Table 1.

Diamond Cross-Sectional Shape: This, the second component, consisting of one or two letters, denotes the cross-sectional shape of the diamond abrasive section. The various shapes and their corresponding letter designations are given in Table 2.

Diamond Section Location: The third component of the symbol consists of a number which gives the location of the diamond section, i.e., periphery, side, corner, etc. An explanation of these numbers is shown in Table 3.

Modification: The fourth component of the symbol is a letter designating some modification, such as drilled and counterbored holes for mounting or special relieving of diamond section or core. This modification position of the symbol is used only when required. The modifications and their designations are given in Table 4.

Table 3. (Continued) Designations for Location of Diamond Section on Diamond Wheel ANSI B74.3-2003 (R2014)

| Designation No. and Location | Description | Illustration |
|------------------------------|--|--------------|
| 9 — Corner | Designates a location which would commonly be considered to be on the periphery except that the diamond section shall be on the corner but shall not extend to the other corner. | |
| 10 — Annular | Designates a location of the diamond abrasive section on the inner annular surface of the wheel. | |

Composition of Diamond and Cubic Boron Nitride Wheels.—According to American National Standard ANSI B74.13-2016, a series of symbols is used to designate the composition of these wheels. An example is shown below.

| Prefix | Abrasive | Grain Size | Grade | Concentration | Bond Type | Bond Modification | Depth of Abrasive | Manufacturer's Identification Symbol |
|--------|----------|------------|-------|---------------|-----------|-------------------|-------------------|--------------------------------------|
| M | D | 120 | R | 100 | B | 56 | 1/8 | * |

Per standard
ANSI
B74.13-2016,
page 3, R
should be N

Fig. 2. Designation Symbols for Composition of Diamond and Cubic Boron Nitride Wheels

The meaning of each symbol is indicated by the following list:

1) *Prefix:* The prefix is a manufacturer's symbol indicating the exact kind of abrasive. Its use is optional.

2) *Abrasive Type:* The letter (B) is used for cubic boron nitride and (D) for diamond.

3) *Grain Size:* The grain sizes commonly used and varying from coarse to very fine are indicated by the following numbers: 8, 10, 12, 14, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, and 220. The following additional sizes are used occasionally: 240, 280, 320, 400, 500, and 600. The wheel manufacturer may add to the regular grain number an additional symbol to indicate a special grain combination.

4) *Grade:* Grades are indicated by letters of the alphabet from A to Z in all bonds or processes. Wheel grades from A to Z range from soft to hard.

5) *Concentration:* The concentration symbol is a manufacturer's designation. It may be a number or a symbol.

6) *Bond:* Bonds are indicated by the following letters: B, resinoid; V, vitrified; M, metal.

7) *Bond Modification:* Within each bond type a manufacturer may have modifications to tailor the bond to a specific application. These modifications may be identified by either letters or numbers.

8) *Abrasive Depth:* Abrasive section depth, in inches or millimeters (inches illustrated), is indicated by a number or letter which is the amount of total dimensional wear a user may expect from the abrasive portion of the product. Most diamond and CBN wheels are made with a depth of coating on the order of $\frac{1}{16}$ in., $\frac{1}{8}$ in., (1.6 mm, 3.2 mm) or more as specified. In some cases the diamond is applied in thinner layers, as thin as one thickness of diamond grains. The L is included in the marking system to identify a layered type product.

9) *Manufacturer's Identification Symbol:* The use of this symbol is optional.

reduce wear and prevent galling, corrosion, and seizure of metals. For use on aluminum, copper, steel, stainless steel, titanium, and chromium, and nickel bearing surfaces.

Types I, II, and III have a thicknesses of 0.008 - 0.013 mm. No single reading less than 0.005 mm or greater than 0.018 mm.

Type I has a curing temperature of $150 \pm 15^\circ\text{C}$ and an endurance life of 250 minutes; Type II, $204 \pm 15^\circ\text{C}$ and 450 minutes; and Type III is a low volatile organic compound (VOC) content lubricant with cure cycles of $150 \pm 15^\circ\text{C}$ for 2 hours, or $204 \pm 15^\circ\text{C}$ for 1 hour with an endurance life of 450 minutes. Color 1 has a natural product color and Color 2 has a black color.

Nickel, QQ-N-290A: There is a nickel finish for almost any need. Nickel can be deposited soft, hard-dull, or bright, depending on process used and conditions employed in plating. Thus, hardness can range from 150–500 HV (Vickers). Nickel can be similar to stainless steel in color, or can be a dull gray (almost white) color. Corrosion resistance is a function of thickness. Nickel has a low coefficient of thermal expansion. All steel parts having a tensile strength of 220,000 or greater shall not be a nickel plate without specific approval of procuring agency.

Class 1 is used for corrosion protection. Plating shall be applied to the following: copper or yellow brass on zinc and zinc based alloys. In no case shall the thickness be substituted for any part of the specified nickel thickness. Class 2 is used in engineering applications.

Grade A has a thickness of 0.0016 inch (41 µm); Grade B, 0.0012 in. (30.48 µm); Grade C, 0.001 in. (25.4 µm); Grade D, 0.0008 in. (20.32 µm); Grade E, 0.0006 in. (15.24 µm); Grade F, 0.0004 in. (10.16 µm); and Grade G, 0.002 in (50.8 µm).

Palladium, MIL-P-45209B: A gray, dense deposit good for undercoats. Has good wear characteristics, corrosion resistance, catalytic properties, and good conductivity. The thickness shall be 0.00005 in. (1.27 µm) unless otherwise specified.

Steel springs and other steel parts subject to flexure or repeated impact and of hardness greater than 40 RC are heated to $375 \pm 25^\circ\text{F}$ ($190 \pm 14^\circ\text{C}$) for 3 hours after plating.

Chemical Passivation, ASTM A967: This process aims to improve the corrosion resistance of parts by removing contaminants from surfaces and facilitating formation of a passive oxide layer. Commercial passivation is performed on austenitic, ferritic, and martensitic stainless steels of the 200, 300, and 400 series, and related variants such as precipitation-hardening stainless steels.

Passivation methods included in the standard are nitric acid immersion, citric acid immersion, and electrochemical treatment (See *Electropolishing, ASTMB912-02 (2018)* on page 1644). Nitric acid has long been used for chemical passivation, but safety and environmental concerns have led to the increasing use of citric acid, when possible. Various grades of stainless steel respond to passivation and related chemistry differently, so care must be taken when specifying a process.

The efficacy of chemical passivation depends on the amount of dynamic contact between the fluid and critical part surfaces. For parts with complex geometry, deep bores, or blind holes, the process may require agitation, repositioning, and use of fixtures.

Phosphate Coating: Light, TT-C-490D: This specification covers cleaning methods and pretreatment processes.

| Methods / Types | Typical Thickness (in.) | Comments |
|------------------|-------------------------|--|
| Cleaning Methods | | |
| Method I | ... | Light coating for use as a paint base. |
| Method II | ... | Mechanical or abrasive cleaning (for ferrous surfaces only). |
| | ... | Used for solvent cleaning. |
| Method III | ... | Used for hot alkalines (for ferrous surfaces only). |
| Method IV | ... | Emulsion. |
| Method V | ... | Used for alkaline derusting (for ferrous surfaces only). |
| Method VI | ... | Phosphoric acid. |

Screw, SAE Grade 8 Steel; and (3) .75 × 5.00 Hex Lag Screw, Steel. (4) $\frac{1}{2}$ -13 Square Nut, Steel, Zinc Plated; (5) $\frac{3}{4}$ -16 Heavy Hex Nut, SAE J995 Grade 5 Steel; and (6) 1000-8 Hex Thick Slotted Nut, ASTM F594 (Alloy Group 1) Corrosion-Resistant Steel.

Table 1. American National Standard and Unified Standard Square Bolts
ANSI/ASME B18.2.1-2012

| SQUARE BOLTS (Fig. 1) | | | | | | | | | | | | |
|---|---------------|---------------------------------|-----------------------------|--------------|--------------|-------------------------------|--------------|----------------------|--------------|--------------|---|--|
| Nominal Size ^a or Basic Product Dia. | | Body Dia. ^b <i>E</i> | Width Across Flats <i>F</i> | | | Width Across Corners <i>G</i> | | Head Height <i>H</i> | | | Thread Length ^c <i>L_T</i> | |
| | | | Max. | Basic | Max. | Min. | Max. | Min. | Basic | Max. | Min. | |
| 1/4 | 0.2500 | 0.260 | 3/8 | 0.375 | 0.362 | 0.530 | 0.498 | 11/64 | 0.188 | 0.156 | 0.750 | |
| 5/16 | 0.3125 | 0.324 | 1/2 | 0.500 | 0.484 | 0.707 | 0.665 | 13/64 | 0.220 | 0.186 | 0.875 | |
| 3/8 | 0.3750 | 0.388 | 9/16 | 0.562 | 0.544 | 0.795 | 0.747 | 1/4 | 0.268 | 0.232 | 1.000 | |
| 7/16 | 0.4375 | 0.452 | 5/8 | 0.625 | 0.603 | 0.884 | 0.828 | 19/64 | 0.316 | 0.278 | 1.125 | |
| 1/2 | 0.5000 | 0.515 | 3/4 | 0.750 | 0.725 | 1.061 | 0.995 | 21/64 | 0.348 | 0.308 | 1.250 | |
| 5/8 | 0.6250 | 0.642 | 15/16 | 0.938 | 0.906 | 1.326 | 1.244 | 27/64 | 0.444 | 0.400 | 1.500 | |
| 3/4 | 0.7500 | 0.768 | 11/8 | 1.125 | 1.088 | 1.591 | 1.494 | 1/2 | 0.524 | 0.476 | 1.750 | |
| 7/8 | 0.8750 | 0.895 | 15/16 | 1.312 | 1.269 | 1.856 | 1.742 | 19/32 | 0.620 | 0.568 | 2.000 | |
| 1 | 1.0000 | 1.022 | 11/2 | 1.500 | 1.450 | 2.121 | 1.991 | 21/32 | 0.684 | 0.628 | 2.250 | |
| 1 1/8 | 1.1250 | 1.149 | 111/16 | 1.688 | 1.631 | 2.386 | 2.239 | 3/4 | 0.780 | 0.720 | 2.500 | |
| 1 1/4 | 1.2500 | 1.277 | 17/8 | 1.875 | 1.812 | 2.652 | 2.489 | 27/32 | 0.876 | 0.812 | 2.750 | |
| 1 3/8 | 1.3750 | 1.404 | 21/16 | 2.602 | 1.994 | 2.917 | 2.738 | 29/32 | 0.940 | 0.872 | 3.000 | |
| 1 1/2 | 1.5000 | 1.531 | 21/4 | 2.250 | 2.175 | 3.182 | 2.986 | 1 | 1.036 | 0.964 | 3.250 | |

2.062

^a Where specifying nominal size in decimals, zeros before the decimal point and in the fourth decimal place are omitted.

^b See *Body Diameter* footnote in Table 3.

^c Thread lengths, *L_T*, shown are for bolt lengths 6 inches and shorter. For longer bolt lengths add 0.250 inch to thread lengths shown.

Table 2. American National Standard Heavy Hex Structural Bolts
ANSI/ASME B18.2.1-1981 (R1992)^a

| HEAVY HEX STRUCTURAL BOLTS (Fig. 2) | | | | | | | | | | | | |
|---|--------|--------------------|-----------------------------|-------|-------------------------------|-------|-----------------|-------|---------------------------|-------|------------------------------------|------------------------|
| Nominal Size ^a or Basic Product Dia. | | Body Dia. <i>E</i> | Width Across Flats <i>F</i> | | Width Across Corners <i>G</i> | | Height <i>H</i> | | Radius of Fillet <i>R</i> | | Thread Length <i>L_T</i> | Trans. Thread <i>Y</i> |
| | | | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Basic | Max. |
| 1/2 | 0.5000 | 0.515 | 0.482 | 0.875 | 0.850 | 1.010 | 0.969 | 0.323 | 0.302 | 0.031 | 0.009 | 1.00 |
| 5/8 | 0.6250 | 0.642 | 0.605 | 1.062 | 1.031 | 1.227 | 1.175 | 0.403 | 0.378 | 0.062 | 0.021 | 1.25 |
| 3/4 | 0.7500 | 0.768 | 0.729 | 1.250 | 1.212 | 1.443 | 1.383 | 0.483 | 0.455 | 0.062 | 0.021 | 1.38 |
| 7/8 | 0.8750 | 0.895 | 0.852 | 1.438 | 1.394 | 1.660 | 1.589 | 0.563 | 0.531 | 0.062 | 0.031 | 1.50 |
| 1 | 1.0000 | 1.022 | 0.976 | 1.625 | 1.575 | 1.876 | 1.796 | 0.627 | 0.591 | 0.093 | 0.062 | 1.75 |
| 1 1/8 | 1.1250 | 1.149 | 1.098 | 1.812 | 1.756 | 2.093 | 2.002 | 0.718 | 0.658 | 0.093 | 0.062 | 2.00 |
| 1 1/4 | 1.2500 | 1.277 | 1.223 | 2.000 | 1.938 | 2.309 | 2.209 | 0.813 | 0.749 | 0.093 | 0.062 | 2.00 |
| 1 3/8 | 1.3750 | 1.404 | 1.345 | 2.188 | 2.119 | 2.526 | 2.416 | 0.878 | 0.810 | 0.093 | 0.062 | 2.25 |
| 1 1/2 | 1.5000 | 1.531 | 1.470 | 2.375 | 2.300 | 2.742 | 2.622 | 0.974 | 0.902 | 0.093 | 0.062 | 2.25 |

^a The table has been included for reference only. Heavy hex structural bolts have been removed from ANSI/ASME B18.2.1 and are now included in ANSI/ASME B18.2.6.

All dimensions are in inches. **Bold type shows bolts unified dimensionally with British and Canadian Standards.** Threads, when rolled, shall be Unified Coarse, Fine, or 8-thread series (UNRC, UNRF, or 8 UNR Series), Class 2A. Threads produced by other methods may be Unified Coarse, Fine, or 8-thread series (UNC, UNF, or 8 UN Series), Class 2A.

Table 4. American National Standard and Unified Standard Heavy Hex Screws and Hex Cap Screws ANSI/ASME B18.2.1-2012

| Nominal Size ^a or Basic Product Dia. | Body Dia. <i>E</i> | | Width Across Flats <i>F</i> | | | Width Across Corners <i>G</i> | | | Height <i>H</i> | | | Thread Length ^b <i>L_T</i> Basic |
|---|-----------------------|---------------|--------------------------------|--------|--------------|----------------------------------|--------------|--------------|--------------------|--------------|--------------|---|
| | Max. | Min. | Basic | Max. | Min. | Max. | Min. | Basic | Max. | Min. | | |
| HEAVY HEX SCREWS (Fig. 4) | | | | | | | | | | | | |
| 3/8 | 0.3750 | 0.3750 | 0.360 | 11/16 | 0.688 | 0.669 | 0.794 | 0.763 | 15/64 | 0.243 | 0.226 | 1.000 |
| 1/2 | 0.5000 | 0.5000 | 0.482 | 7/8 | 0.875 | 0.850 | 1.010 | 0.969 | 5/16 | 0.323 | 0.302 | 1.250 |
| 5/8 | 0.6250 | 0.6250 | 0.605 | 11/16 | 1.062 | 1.031 | 1.227 | 1.175 | 25/64 | 0.403 | 0.378 | 1.500 |
| 3/4 | 0.7500 | 0.7500 | 0.729 | 11/4 | 1.250 | 1.212 | 1.443 | 1.383 | 15/32 | 0.483 | 0.455 | 1.750 |
| 7/8 | 0.8750 | 0.8750 | 0.852 | 17/16 | 1.438 | 1.394 | 1.660 | 1.589 | 35/64 | 0.563 | 0.531 | 2.000 |
| 1 | 1.0000 | 1.0000 | 0.976 | 15/8 | 1.625 | 1.575 | 1.876 | 1.796 | 39/64 | 0.627 | 0.591 | 2.250 |
| 1 1/8 | 1.1250 | 1.1250 | 1.098 | 113/16 | 1.812 | 1.756 | 2.093 | 2.002 | 11/16 | 0.718 | 0.658 | 2.500 |
| 1 1/4 | 1.2500 | 1.2500 | 1.223 | 2 | 2.000 | 1.938 | 2.309 | 2.209 | 25/32 | 0.813 | 0.749 | 2.750 |
| 1 3/8 | 1.3750 | 1.3750 | 1.345 | 23/16 | 2.188 | 2.119 | 2.526 | 2.416 | 27/32 | 0.878 | 0.810 | 3.000 |
| 1 1/2 | 1.5000 | 1.5000 | 1.470 | 25/8 | 2.375 | 2.300 | 2.742 | 2.622 | 15/16 | 0.974 | 0.902 | 3.250 |
| 1 5/8 | 1.6250 | 1.6250 | 1.591 | 29/16 | 2.562 | 2.481 | 2.959 | 2.829 | 1 | 1.038 | 0.962 | 3.500 |
| 1 3/4 | 1.7500 | 1.7500 | 1.716 | 23/4 | 2.750 | 2.662 | 3.175 | 3.035 | 13/32 | 1.134 | 1.054 | 3.750 |
| 1 7/8 | 1.8750 | 1.8750 | 1.839 | 215/16 | 2.938 | 2.844 | 3.392 | 3.242 | 15/32 | 1.198 | 1.114 | 4.000 |
| 2 | 2.0000 | 2.0000 | 1.964 | 31/8 | 3.125 | 3.025 | 3.608 | 3.449 | 17/32 | 1.263 | 1.175 | 4.250 |
| 2 1/4 | 2.2500 | 2.2500 | 2.214 | 31/2 | 3.500 | 3.388 | 4.041 | 3.862 | 13/8 | 1.423 | 1.327 | 5.000 ^c |
| 2 1/2 | 2.5000 | 2.5000 | 2.461 | 37/8 | 3.875 | 3.750 | 4.474 | 4.275 | 117/32 | 1.583 | 1.479 | 5.500 ^c |
| 2 3/4 | 2.7500 | 2.7500 | 2.711 | 41/4 | 4.250 | 41.112 | 4.907 | 4.688 | 111/16 | 1.744 | 1.632 | 6.000 ^c |
| 3 | 3.0000 | 3.0000 | 2.961 | 45/8 | 4.625 | 4.475 | 5.340 | 5.102 | 17/8 | 1.935 | 1.815 | 6.500 ^c |
| 3 1/4 | 3.2500 | 3.2500 | 3.210 | 5 | 5.000 | 4.838 | 5.774 | 5.515 | 2 | 2.126 | 1.998 | 7.000 ^c |
| 3 1/2 | 3.5000 | 3.5000 | 3.461 | 53/8 | 5.375 | 5.200 | 6.207 | 5.928 | 21/4 | 2.256 | 2.120 | 7.500 ^c |
| 3 3/4 | 3.7500 | 3.7500 | 3.711 | 53/4 | 5.750 | 5.562 | 6.640 | 6.341 | 23/8 | 2.447 | 2.303 | 8.000 ^c |
| 4 | 4.0000 | 4.0000 | 3.961 | 61/8 | 6.125 | 5.925 | 7.073 | 6.755 | 21/2 | 2.576 | 2.424 | 8.500 ^c |
| 4 1/4 | 4.2500 | 4.2500 | 4.223 | 61/2 | 6.500 | 6.288 | 7.506 | 7.168 | 23/4 | 2.768 | 2.608 | 9.000 ^c |
| 4 1/2 | 4.5000 | 4.5000 | 4.473 | 67/8 | 6.875 | 6.650 | 7.939 | 7.581 | 27/8 | 2.896 | 2.728 | 9.500 ^c |
| 4 3/4 | 4.7500 | 4.7500 | 4.723 | 71/4 | 7.250 | 7.012 | 8.372 | 7.994 | 3 | 3.088 | 2.912 | 10.000 ^c |
| 5 | 5.0000 | 5.0000 | 4.973 | 75/8 | 7.625 | 7.375 | 8.805 | 8.408 | 31/8 | 3.217 | 3.033 | 10.500 ^c |
| 5 1/4 | 5.2500 | 5.2500 | 5.223 | 8 | 8.000 | 7.738 | 9.238 | 8.821 | 33/8 | 3.408 | 3.216 | 11.000 ^c |
| 5 1/2 | 5.5000 | 5.5000 | 5.473 | 83/8 | 8.375 | 8.100 | 9.671 | 9.234 | 31/2 | 3.538 | 3.338 | 11.500 ^c |
| 5 3/4 | 5.7500 | 5.7500 | 5.723 | 83/4 | 8.750 | 8.462 | 10.104 | 9.647 | 35/8 | 3.729 | 3.521 | 12.000 ^c |
| 6 | 6.0000 | 6.0000 | 5.973 | 91/8 | 9.125 | 8.825 | 10.537 | 10.060 | 33/4 | 3.858 | 3.642 | 12.500 ^c |
| HEX CAP SCREWS (Finished Hex Bolts) (Fig. 4) | | | | | | | | | | | | |
| 1/4 | 0.2500 | 0.2500 | 0.2450 | 7/16 | 0.438 | 0.428 | 0.505 | 0.488 | 5/32 | 0.163 | 0.150 | 0.750 |
| 5/16 | 0.3125 | 0.3125 | 0.3065 | 1/2 | 0.500 | 0.489 | 0.577 | 0.557 | 13/64 | 0.211 | 0.195 | 0.875 |
| 3/8 | 0.3750 | 0.3750 | 0.3690 | 9/16 | 0.562 | 0.551 | 0.650 | 0.628 | 15/64 | 0.243 | 0.226 | 1.000 |
| 7/16 | 0.4375 | 0.4375 | 0.4305 | 5/8 | 0.625 | 0.612 | 0.722 | 0.698 | 9/32 | 0.291 | 0.272 | 1.125 |
| 1/2 | 0.5000 | 0.5000 | 0.4930 | 3/4 | 0.750 | 0.736 | 0.866 | 0.840 | 5/16 | 0.323 | 0.302 | 1.250 |
| 9/16 | 0.5625 | 0.5625 | 0.5545 | 13/16 | 0.812 | 0.798 | 0.938 | 0.910 | 23/64 | 0.371 | 0.348 | 1.375 |
| 5/8 | 0.6250 | 0.6250 | 0.6170 | 15/16 | 0.938 | 0.922 | 1.083 | 1.051 | 25/64 | 0.403 | 0.378 | 1.500 |
| 3/4 | 0.7500 | 0.7500 | 0.7410 | 11/8 | 1.125 | 1.100 | 1.299 | 1.254 | 15/32 | 0.483 | 0.455 | 1.750 |
| 7/8 | 0.8750 | 0.8750 | 0.8660 | 15/16 | 1.312 | 1.285 | 1.516 | 1.465 | 35/64 | 0.563 | 0.531 | 2.000 |
| 1 | 1.0000 | 1.0000 | 0.9900 | 11/2 | 1.500 | 1.469 | 1.732 | 1.675 | 39/64 | 0.627 | 0.591 | 2.250 |
| 1 1/8 | 1.1250 | 1.1250 | 1.1140 | 111/16 | 1.688 | 1.631 | 1.949 | 1.859 | 11/16 | 0.718 | 0.658 | 2.500 |
| 1 1/4 | 1.2500 | 1.2500 | 1.2390 | 17/8 | 1.875 | 1.812 | 2.165 | 2.066 | 25/32 | 0.813 | 0.749 | 2.750 |
| 1 3/8 | 1.3750 | 1.3750 | 1.3630 | 21/16 | 2.062 | 1.994 | 2.382 | 2.273 | 27/32 | 0.878 | 0.810 | 3.000 |
| 1 1/2 | 1.5000 | 1.5000 | 1.4880 | 21/4 | 2.250 | 2.175 | 2.598 | 2.480 | 15/16 | 0.974 | 0.902 | 3.250 |
| 1 5/8 | 1.6250 | 1.6250 | 1.6130 | 27/16 | 2.438 | 2.356 | 2.815 | 2.686 | 1 | 1.038 | 0.962 | 3.500 |
| 1 3/4 | 1.7500 | 1.7500 | 1.7380 | 25/8 | 2.625 | 2.538 | 3.031 | 2.893 | 13/32 | 1.134 | 1.054 | 3.750 |
| 1 7/8 | 1.8750 | 1.8750 | 1.8630 | 213/16 | 2.812 | 2.719 | 3.248 | 3.099 | 15/32 | 1.198 | 1.114 | 4.000 |
| 2 | 2.0000 | 2.0000 | 1.9880 | 3 | 3.000 | 2.900 | 3.464 | 3.306 | 17/32 | 1.263 | 1.175 | 4.250 |
| 2 1/4 | 2.2500 | 2.2500 | 2.2380 | 33/8 | 3.375 | 3.262 | 3.897 | 3.719 | 13/8 | 1.423 | 1.327 | 5.000 ^c |
| 2 1/2 | 2.5000 | 2.5000 | 2.4880 | 33/4 | 3.750 | 3.625 | 4.330 | 4.133 | 17/32 | 1.583 | 1.479 | 5.500 ^c |
| 2 3/4 | 2.7500 | 2.7500 | 2.7380 | 41/8 | 4.125 | 3.988 | 4.763 | 4.546 | 111/16 | 1.744 | 1.632 | 6.000 ^c |
| 3 | 3.0000 | 3.0000 | 2.9880 | 41/2 | 4.500 | 4.350 | 5.196 | 4.959 | 17/8 | 1.935 | 1.815 | 6.500 ^c |

^a Nominal Size: Where specifying nominal size in decimals, zeros preceding the decimal and in the fourth decimal place are omitted.

^b Thread lengths, *L_T*, shown are for bolt lengths 6 inches and shorter. For longer bolt lengths add 0.250 inch to thread lengths shown.

^c Thread lengths, *L_T*, shown are for bolt lengths over 6 inches.

All dimensions are in inches.

Unification: Bold type indicates product features unified dimensionally with British and Canadian Standards. Unification of fine thread products is limited to sizes 1 inch and smaller.

Bearing Surface: Bearing surface is flat and washer faced. Diameter of bearing surface is equal to the maximum width across flats within a tolerance of minus 10 percent.

Threads Series: Threads, when rolled, are Unified Coarse, Fine, or 8-thread series (UNRC, UNRF, or 8 UNR Series), Class 2A. Threads produced by other methods shall preferably be UNRC, UNRF or 8 UNR but, at manufacturer's option, may be Unified Coarse, Fine or 8-thread series (UNC, UNF, or 8 UN Series), Class 2A.

Material: Chemical and mechanical properties of steel screws normally conform to Grades 2, 5, or 8 of SAE J429, ASTM A449 or ASTM A354 Grade BD. Where specified, screws may also be made from brass, bronze, corrosion-resisting steel, aluminum alloy or other materials.

Table 1. Wrench Openings for Nuts ANSI/ASME B18.2.2-2015, Appendix

| Max. ^a Width Across Flats of Nut | Wrench Opening ^b | | Max. ^a Width Across Flats of Nut | Wrench Opening ^b | | Max. ^a Width Across Flats of Nut | Wrench Opening ^b | |
|---|-----------------------------|-------|---|-----------------------------|-------|---|-----------------------------|-------|
| | Min. | Max. | | Min. | Max. | | Min. | Max. |
| 5/32 | 0.158 | 0.163 | 1 1/4 | 1.257 | 1.267 | 2 15/16 | 2.954 | 2.973 |
| 3/16 | 0.190 | 0.195 | 1 5/16 | 1.320 | 1.331 | 3 | 3.016 | 3.035 |
| 7/32 | 0.220 | 0.225 | 1 3/8 | 1.383 | 1.394 | 3 1/8 | 3.142 | 3.162 |
| 1/4 | 0.252 | 0.257 | 1 7/16 | 1.446 | 1.457 | 3 3/8 | 3.393 | 3.414 |
| 9/32 | 0.283 | 0.288 | 1 1/2 | 1.508 | 1.520 | 3 1/2 | 3.518 | 3.540 |
| 5/16 | 0.316 | 0.322 | 1 5/8 | 1.634 | 1.646 | 3 3/4 | 3.770 | 3.793 |
| 11/32 | 0.347 | 0.353 | 1 11/16 | 1.696 | 1.708 | 3 7/8 | 3.895 | 3.918 |
| 3/8 | 0.378 | 0.384 | 1 13/16 | 1.822 | 1.835 | 4 1/8 | 4.147 | 4.172 |
| 7/16 | 0.440 | 0.446 | 1 7/8 | 1.885 | 1.898 | 4 1/4 | 4.272 | 4.297 |
| 1/2 | 0.504 | 0.510 | 2 | 2.011 | 2.025 | 4 1/2 | 4.524 | 4.550 |
| 9/16 | 0.566 | 0.573 | 2 1/16 | 2.074 | 2.088 | 4 5/8 | 4.649 | 4.676 |
| 5/8 | 0.629 | 0.636 | 2 3/16 | 2.200 | 2.215 | 4 7/8 | 4.900 | 4.928 |
| 11/16 | 0.692 | 0.699 | 2 1/4 | 2.262 | 2.277 | 5 | 5.026 | 5.055 |
| 3/4 | 0.755 | 0.763 | 2 3/8 | 2.388 | 2.404 | 5 1/4 | 5.277 | 5.307 |
| 13/16 | 0.818 | 0.826 | 2 7/16 | 2.450 | 2.466 | 5 3/8 | 5.403 | 5.434 |
| 7/8 | 0.880 | 0.888 | 2 9/16 | 2.576 | 2.593 | 5 5/8 | 5.654 | 5.686 |
| 15/16 | 0.944 | 0.953 | 2 5/8 | 2.639 | 2.656 | 5 3/4 | 5.780 | 5.813 |
| 1 | 1.006 | 1.015 | 2 3/4 | 2.766 | 2.783 | 6 | 6.031 | 6.157 |
| 1 1/16 | 1.068 | 1.077 | 2 13/16 | 2.827 | 2.845 | 6 1/8 | 6.065 | 6.192 |
| 1 1/8 | 1.132 | 1.142 | | | | | | |

^a Wrenches are marked with the “Nominal Size of Wrench,” which is equal to the basic or maximum width across flats of the corresponding nut. Minimum wrench opening is $(1.005W + 0.001)$. Tolerance on wrench opening is $(0.005W + 0.004)$ from minimum, where W equals nominal size of wrench.

^b Openings for $5/32$ to $3/8$ widths from old ASA B18.2-1960 and italic values are from former ANSI B18.2.2-1972.

All dimensions given in inches.

Table 2. Clearances for Open End Engineers Wrench (15°)

| Nominal Wrench Size | A Min. (in.) | B ^a Max. (in.) | C Min. (in.) | D Min. (in.) | E Min. (in.) | F ^b Max. (in.) | G Ref. (in.) | H ^c Max. (in.) | J Min. ^d in.-lbf |
|------------------------|-----------------|------------------------------|-----------------|-----------------|-----------------|------------------------------|-----------------|------------------------------|--------------------------------|
| 5/32 | 0.156 | 0.220 | 0.250 | 0.390 | 0.160 | 0.250 | 0.200 | 0.094 | 35 |
| 3/16 | 0.188 | 0.250 | 0.280 | 0.430 | 0.190 | 0.270 | 0.230 | 0.172 | 45 |
| 1/4 | 0.250 | 0.280 | 0.340 | 0.530 | 0.270 | 0.310 | 0.310 | 0.172 | 67 |
| 5/16 | 0.313 | 0.380 | 0.470 | 0.660 | 0.280 | 0.390 | 0.390 | 0.050 | 138 |
| 11/32 | 0.344 | 0.420 | 0.500 | 0.750 | 0.340 | 0.450 | 0.450 | 0.050 | 193 |
| 3/8 | 0.375 | 0.420 | 0.500 | 0.780 | 0.360 | 0.450 | 0.520 | 0.050 | 275 |
| 7/16 | 0.438 | 0.470 | 0.590 | 0.890 | 0.420 | 0.520 | 0.640 | 0.050 | 413 |
| 1/2 | 0.500 | 0.520 | 0.640 | 1.000 | 0.470 | 0.580 | 0.660 | 0.050 | 550 |
| 9/16 | 0.563 | 0.590 | 0.770 | 1.130 | 0.520 | 0.660 | 0.700 | 0.050 | 770 |
| 5/8 | 0.625 | 0.640 | 0.830 | 1.230 | 0.550 | 0.700 | 0.700 | 0.050 | 1100 |
| 11/16 | 0.688 | 0.770 | 0.920 | 1.470 | 0.660 | 0.880 | 0.800 | 0.060 | 1375 |
| 3/4 | 0.750 | 0.770 | 0.920 | 1.510 | 0.670 | 0.880 | 0.800 | 0.060 | 1650 |
| 13/16 | 0.813 | 0.910 | 1.120 | 1.660 | 0.720 | 0.970 | 0.860 | 0.060 | 2200 |
| 7/8 | 0.875 | 0.970 | 1.150 | 1.810 | 0.800 | 1.060 | 0.910 | 0.060 | 2475 |
| 15/16 | 0.938 | 0.970 | 1.150 | 1.850 | 0.810 | 1.060 | 0.950 | 0.060 | 3025 |
| 1 | 1.000 | 1.050 | 1.230 | 2.000 | 0.880 | 1.160 | 1.060 | 0.060 | 3575 |
| 1 1/16 | 1.063 | 1.090 | 1.250 | 2.100 | 0.970 | 1.200 | 1.200 | 0.080 | 3850 |
| 1 1/8 | 1.125 | 1.140 | 1.370 | 2.210 | 1.000 | 1.270 | 1.230 | 0.080 | 4400 |
| 1 1/4 | 1.250 | 1.270 | 1.420 | 2.440 | 1.080 | 1.390 | 1.310 | 0.080 | 5775 |
| 1 5/16 | 1.313 | 1.390 | 1.690 | 2.630 | 1.170 | 1.520 | 1.340 | 0.080 | 6600 |
| 1 7/16 | 1.438 | 1.470 | 1.720 | 2.800 | 1.250 | 1.590 | 1.340 | 0.090 | 8250 |
| 1 1/2 | 1.500 | 1.470 | 1.720 | 2.840 | 1.270 | 1.590 | 1.450 | 0.090 | 8500 |
| 1 5/8 | 1.625 | 1.560 | 1.880 | 3.100 | 1.380 | 1.750 | 1.560 | 0.090 | 9000 |

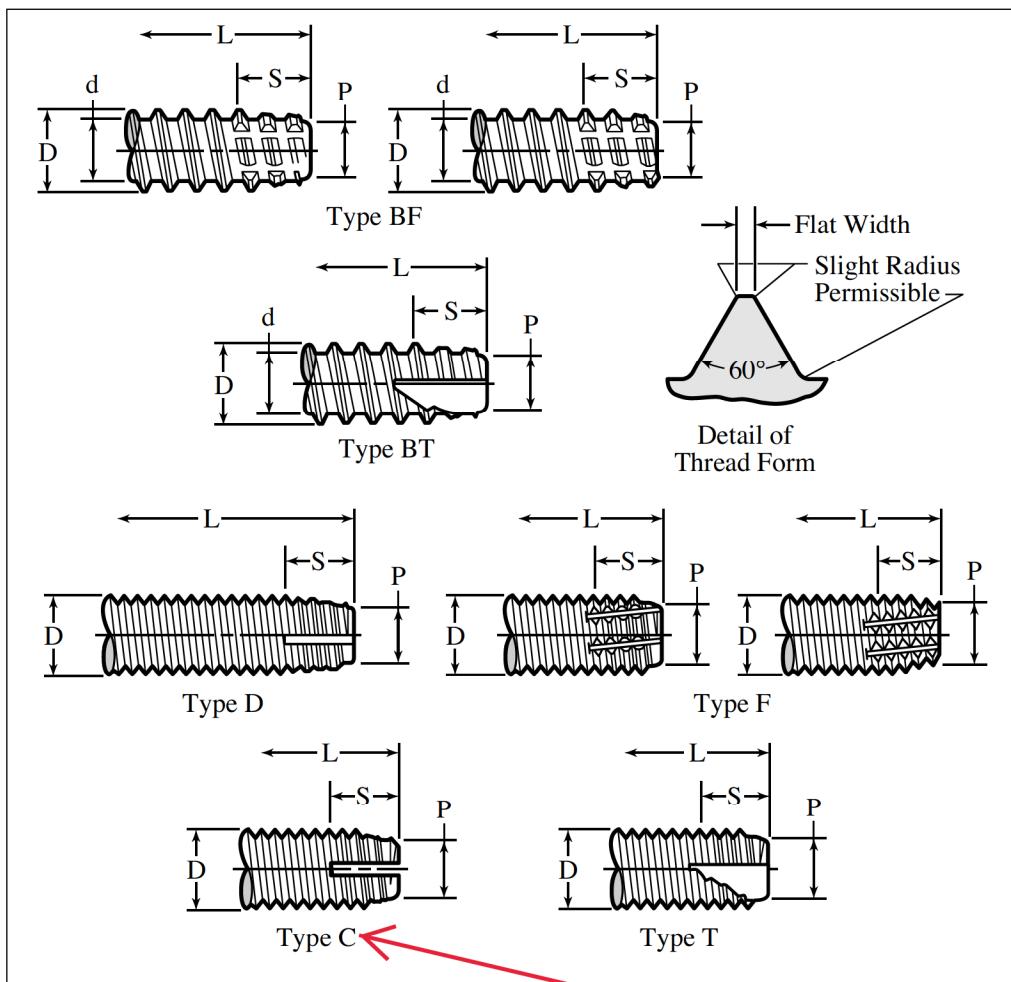
^a B = arc radius created by the swing of the wrench.

^b F = inside arc radius of part.

^c H = thickness of wrench head. (Dimension line not shown.)

^d J = torque that wrench will withstand in inch-pounds. Values updated from ANSI/ASME B107.100-2010, Wrenches.

Table 2. ANSI Standard Threads and Points for Thread Cutting Self-Tapping Screws ANSI/ASME B18.6.3-2013



See Table 5 and Table 7 for thread data.

Change to
"Type G"

Cross Recesses.—Type I cross recess has a large center opening, tapered bottom, with all edges relieved or rounded. Type IA cross recess has a large center opening, wide straight wings, and blunt bottom, with all edges relieved or rounded. Type II consists of two intersecting slots with parallel sides converging to a slightly truncated apex at the bottom of the recess. Type III has a square center opening, slightly tapered side walls, and a conical bottom, with top edges relieved or rounded.

Table 3. ANSI Standard Cross Recesses for Self-Tapping Screws ANSI/ASME B18.6.3-2013 and Metric Thread Forming and Thread Cutting Tapping Screws ANSI/ASME B18.6.5M-2000 (Withdrawn)

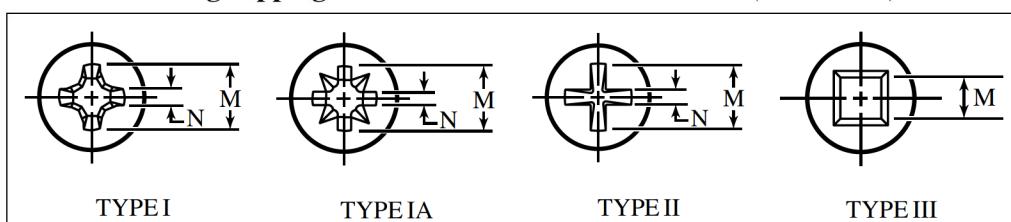


Table 3. (Continued) Standard Series and Selected Combinations—Unified Screw Threads

| Nominal Size, Threads per Inch, and Series Designation ^a | Class | Allow- ance | External ^b | | | | Internal ^b | | | | Major Diameter Min |
|--|--------|----------------|-----------------------|--------|----------------|----------------|-----------------------|--------|----------------|----------------|--------------------------|
| | | | Max ^d | Min | Major Diameter | Pitch Diameter | Min | Max | Minor Diameter | Pitch Diameter | |
| 7/8-24 UNS | 2A | 0.0012 | 0.8738 | 0.8666 | — | 0.8467 | 0.8425 | 0.8242 | 2B | 0.830 | 0.840 |
| 7/8-27 UNS | 2A | 0.0012 | 0.8738 | 0.8671 | — | 0.8497 | 0.8457 | 0.8297 | 2B | 0.835 | 0.844 |
| 7/8-28 UN | 2A | 0.0012 | 0.8738 | 0.8673 | — | 0.8506 | 0.8467 | 0.8313 | 2B | 0.836 | 0.845 |
| 7/8-32 UN | 3A | 0.0000 | 0.8750 | 0.8685 | — | 0.8518 | 0.8489 | 0.8325 | 3B | 0.8360 | 0.8426 |
| 2A | 0.0011 | 0.8739 | 0.8679 | — | 0.8536 | 0.8499 | 0.8367 | 2B | 0.841 | 0.849 | |
| 3A | 0.0000 | 0.8750 | 0.8690 | — | 0.8547 | 0.8519 | 0.8378 | 3B | 0.8410 | 0.8469 | |
| 1 5/16-12 UN | 2A | 0.0017 | 0.9358 | 0.9244 | — | 0.8817 | 0.8761 | 0.8366 | 2B | 0.847 | 0.865 |
| 3A | 0.0000 | 0.9375 | 0.9261 | — | 0.8834 | 0.8792 | 0.8383 | 3B | 0.8470 | 0.8575 | |
| 2A | 0.0015 | 0.9360 | 0.9266 | — | 0.8954 | 0.8904 | 0.8616 | 2B | 0.870 | 0.884 | |
| 3A | 0.0000 | 0.9375 | 0.9281 | — | 0.8969 | 0.8932 | 0.8631 | 3B | 0.8700 | 0.8784 | |
| 15/16-20 UNEF | 2A | 0.0014 | 0.9361 | 0.9280 | — | 0.9036 | 0.8991 | 0.8766 | 2B | 0.883 | 0.895 |
| 3A | 0.0000 | 0.9375 | 0.9294 | — | 0.9050 | 0.9016 | 0.8780 | 3B | 0.8830 | 0.8911 | |
| 1 5/16-28 UN | 2A | 0.0012 | 0.9363 | 0.9298 | — | 0.9131 | 0.9092 | 0.8938 | 2B | 0.899 | 0.907 |
| 3A | 0.0000 | 0.9375 | 0.9310 | — | 0.9143 | 0.9113 | 0.8950 | 3B | 0.8990 | 0.9051 | |
| 1 5/16-32 UN | 2A | 0.0011 | 0.9364 | 0.9304 | — | 0.9161 | 0.9123 | 0.8992 | 2B | 0.904 | 0.911 |
| 3A | 0.0000 | 0.9375 | 0.9315 | — | 0.9172 | 0.9144 | 0.9003 | 3B | 0.9040 | 0.9094 | |
| 1A | 0.0020 | 0.9980 | 0.9755 | — | 0.9168 | 0.9067 | 0.8492 | 1B | 0.865 | 0.890 | |
| 2A | 0.0020 | 0.9980 | 0.9830 | 0.9755 | 0.9168 | 0.9101 | 0.8492 | 2B | 0.865 | 0.890 | |
| 1-10 UNS | 2A | 0.0000 | 1.0000 | 0.9850 | — | 0.9188 | 0.9137 | 0.8512 | 3B | 0.8650 | 0.8797 |
| 1A | 0.0018 | 0.9982 | 0.9853 | — | 0.9332 | 0.9270 | 0.8791 | 2B | 0.892 | 0.913 | |
| 1-12 UNF | 1A | 0.0018 | 0.9982 | 0.9810 | — | 0.9441 | 0.9353 | 0.8990 | 1B | 0.910 | 0.928 |
| 2A | 0.0018 | 0.9982 | 0.9868 | — | 0.9441 | 0.9382 | 0.8990 | 2B | 0.910 | 0.928 | |
| 3A | 0.0000 | 1.0000 | 0.9886 | — | 0.9459 | 0.9415 | 0.9008 | 3B | 0.9100 | 0.9198 | |
| 1-14 UNS ^f | 1A | 0.0017 | 0.9983 | 0.9828 | — | 0.9519 | 0.9435 | 0.9132 | 1B | 0.923 | 0.938 |
| 2A | 0.0016 | 0.9894 | 0.9881 | — | 0.9520 | 0.9467 | 0.9133 | 2B | 0.923 | 0.938 | |
| 3A | 0.0000 | 1.0000 | 0.9897 | — | 0.9536 | 0.9496 | 0.9149 | 3B | 0.9230 | 0.9315 | |
| 1-16 UN | 2A | 0.0015 | 0.9985 | 0.9891 | — | 0.9579 | 0.9529 | 0.9241 | 2B | 0.932 | 0.946 |
| 3A | 0.0000 | 1.0000 | 0.9906 | — | 0.9594 | 0.9557 | 0.9256 | 3B | 0.9320 | 0.9409 | |
| 1-18 UNS | 2A | 0.0014 | 0.9986 | 0.9899 | — | 0.9625 | 0.9578 | 0.9324 | 2B | 0.940 | 0.953 |

.9894 should be .9984

PLEASE NOTE: In future editions of the MH, the data for 1-14UNS-1A, which is no longer referenced as a nominal size and class in the official Standard, will be omitted from this table.

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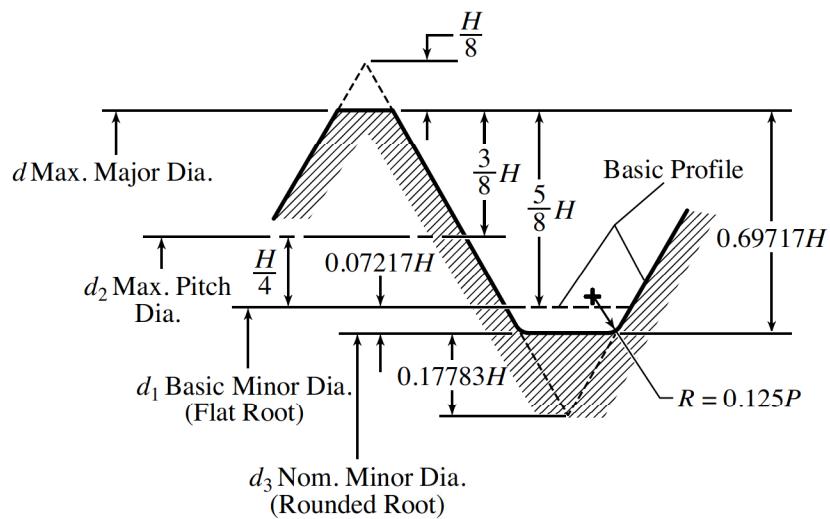


Fig. 3. External Thread Design M Profile with No Allowance (Fundamental Deviation) (Flanks at Maximum Material Condition). For Dimensions see Table 3

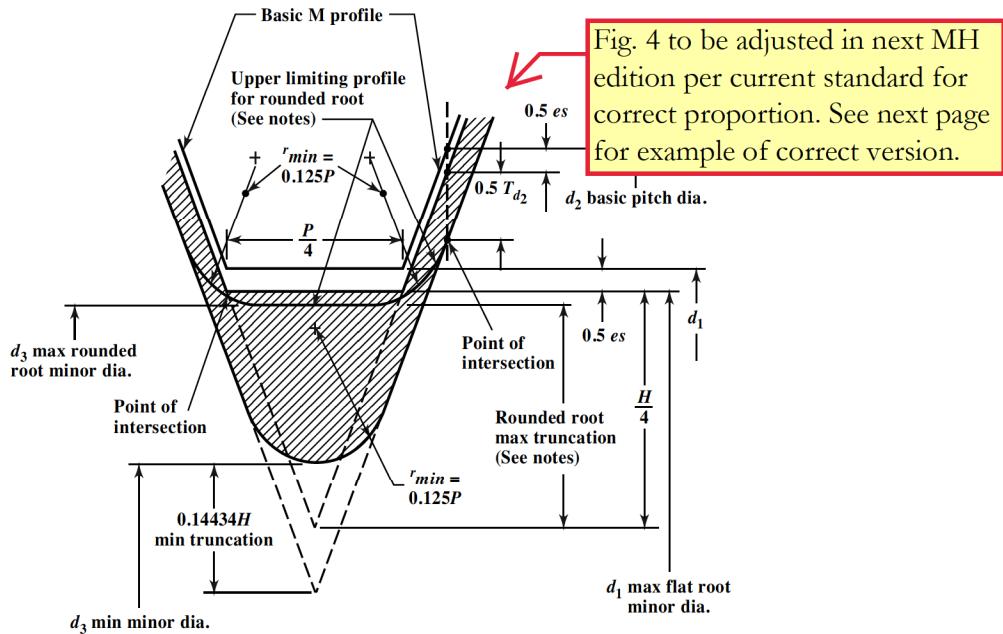


Fig. 4. M Profile, External Thread Root, Upper and Lower Limiting Profiles for $r_{min} = 0.125 P$ and for Flat Root (Shown for Tolerance Position g)

Notes:

- 1) "Section lined" portions identify tolerance zone and unshaded portions identify allowance (fundamental deviation).
- 2) The upper limiting profile for rounded root is not a design profile; rather it indicates the limiting acceptable condition for the rounded root which will pass a GO thread gage.
- 3) Max truncation = $\frac{H}{4} - r_{min} \left(1 - \cos \left[60^\circ - \arccos \left(1 - \frac{T_{d2}}{4r_{min}} \right) \right] \right)$

where H = Height of fundamental triangle

r_{min} = Minimum external thread root radius

T_{d2} = Tolerance on pitch diameter of external threads

The below showing the revised proportion of p. 2018, Fig. 4, for future adjustment of this figure, per the ASME standard, is shown below.

METRIC SCREW THREADS: M PROFILE

ASME B1.13M-2005

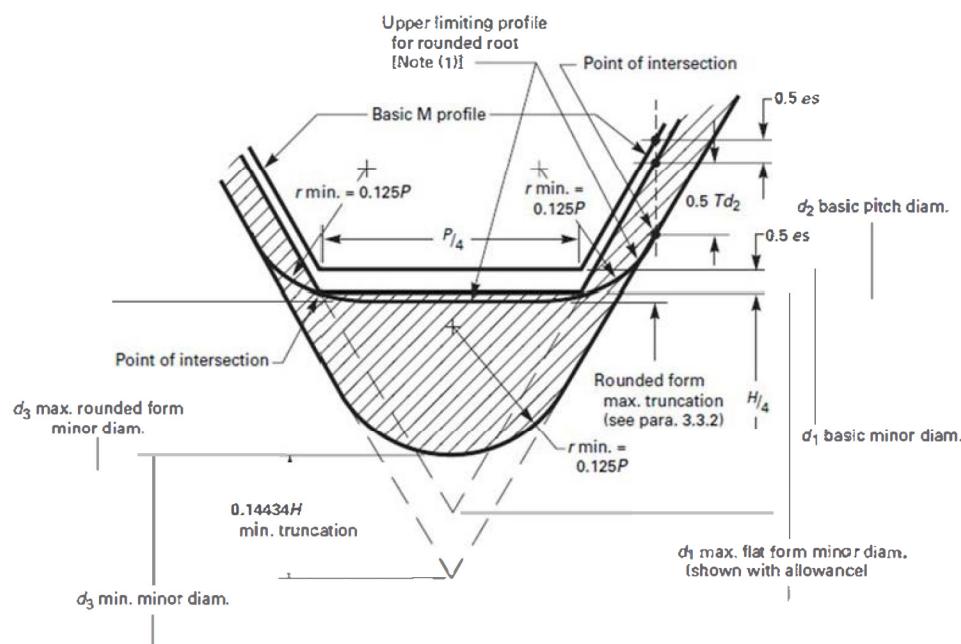


Fig. 5 M Profile, External Thread Root, Upper and Lower Limiting Profiles for $r_{\min.} = 0.125P$ and for Flat Root Form (Shown for Tolerance Position g)

The above material from ASME B1.13M-2005 is reproduced here, courtesy of ASME, for illustration purposes regarding this page change only. ©ASME. All rights reserved.

Internal Threads:

Min major dia. = basic major dia. + *EI* (Table 6)

Min pitch dia. = basic major dia. - 0.6495191*P* (Table 3) + *EI* for *D*₂ (Table 6)

Max pitch dia. = min pitch dia. + *TD*₂ (Table 10)

Max major dia. = max pitch dia. + 0.7938566*P* (Table 3)

Min minor dia. = min major dia. - 1.0825318*P* (Table 3)

Max minor dia. = min minor dia. + *TD*₁ (Table 8)

External Threads:

Max major dia. = basic major dia. - *es* (Table 6) (Note that *es* is an absolute value.)

Min major dia. = max major dia. - *Td* (Table 9)

Max pitch dia. = basic major dia. - 0.6495191*P* (Table 3) - *es* for *d*₂ (Table 6)

Min pitch dia. = max pitch dia. - *Td*₂ (Table 11)

Max flat form minor dia. = max pitch dia. - 0.433013*P* (Table 3)

Max rounded root minor dia. = max pitch dia. - 2 × max trunc. (See Fig. 4)

Min rounded root minor dia. = min pitch dia. - 0.616025*P* (Table 3)

Min root radius = 0.125*P*

Table 8. ANSI Standard Minor Dimensions for Metric Threads TD₁ ISO 965/1 A

| Pitch <i>P</i> | T ₁ | | T ₂ | | T ₃ | |
|-------------------|----------------|-------|----------------|-------|----------------|---|
| | 4 | 5 | 4 | 5 | 4 | 5 |
| 0.2 | 0.038 | ... | | | | |
| 0.25 | 0.045 | 0.056 | | | | |
| 0.3 | 0.053 | 0.067 | 0.085 | ... | ... | |
| 0.35 | 0.063 | 0.080 | 0.100 | ... | ... | |
| 0.4 | 0.071 | 0.090 | 0.112 | ... | ... | |
| 0.45 | 0.080 | 0.100 | 0.125 | ... | ... | |
| 0.5 | 0.090 | 0.112 | 0.140 | 0.180 | ... | |
| 0.6 | 0.100 | 0.125 | 0.160 | 0.200 | ... | |
| 0.7 | 0.112 | 0.140 | 0.180 | 0.224 | ... | |
| 0.75 | 0.118 | 0.150 | 0.190 | 0.236 | ... | |
| 0.8 | 0.125 | 0.160 | 0.200 | 0.250 | 0.315 | |
| 1 | 0.150 | 0.190 | 0.236 | 0.300 | 0.375 | |
| 1.25 | 0.170 | 0.212 | 0.265 | 0.335 | 0.425 | |
| 1.5 | 0.190 | 0.236 | 0.300 | 0.375 | 0.475 | |
| 1.75 | 0.212 | 0.265 | 0.335 | 0.425 | 0.530 | |
| 2 | 0.236 | 0.300 | 0.375 | 0.475 | 0.600 | |
| 2.5 | 0.280 | 0.355 | 0.450 | 0.560 | 0.710 | |
| 3 | 0.315 | 0.400 | 0.500 | 0.630 | 0.800 | |
| 3.5 | 0.355 | 0.450 | 0.560 | 0.710 | 0.900 | |
| 4 | 0.375 | 0.475 | 0.600 | 0.750 | 0.950 | |
| 4.5 | 0.425 | 0.530 | 0.670 | 0.850 | 1.060 | |
| 5 | 0.450 | 0.560 | 0.710 | 0.900 | 1.120 | |
| 5.5 | 0.475 | 0.600 | 0.750 | 0.950 | 1.180 | |
| 6 | 0.500 | 0.630 | 0.800 | 1.000 | 1.250 | |
| 8 | 0.630 | 0.800 | 1.000 | 1.250 | 1.600 | |

^a Tabulated in this standard for M internal threads.

All dimensions are in millimeters.

Equation identified as incorrect in older ANSI standard; not in new standard. Correct to read:

Max rounded root minor dia. = max pitch dia.
- H + 2 × max trunc. (see Fig. 4)

Corrected 1.0700 (previously
was incorrectly 0.0700)

CENTRALIZING ACME SCREW THREADS

2067

**Table 8b. Limiting Dimensions of American National Standard Centralizing Acme Single-Start Screw Threads,
Classes 2C, 3C, and 4C ANSI/ASME B1.5-1997 (R2014)**

| Limiting Diameters | Nominal Diameter, D Threads per Inch ^a | External Threads | | | | Internal Threads | | | |
|--|--|------------------|--------|--------|--------|------------------|--------|--------|--------|
| | | 10 | 8 | 6 | 5 | 5 | 5 | 4 | 4 |
| Classes 2C, 3C, and 4C, Major Diameter | Max | 0.5000 | 0.6250 | 0.7500 | 0.8750 | 1.0000 | 1.1250 | 1.2500 | 1.3750 |
| Class 2C, Major Diameter | Min | 0.4975 | 0.6222 | 0.7470 | 0.8717 | 0.9965 | 1.1213 | 1.2461 | 1.3709 |
| Class 3C, Major Diameter | Min | 0.4989 | 0.6238 | 0.7487 | 0.8736 | 0.9985 | 1.1234 | 1.2483 | 1.3732 |
| Class 4C, Major Diameter | Min | 0.4993 | 0.6242 | 0.7491 | 0.8741 | 0.9990 | 1.1239 | 1.2489 | 1.3738 |
| Classes 2C, 3C, and 4C, Minor Diameter | Max | 0.3800 | 0.4800 | 0.5633 | 0.6883 | 0.7800 | 0.9050 | 1.0300 | 1.1050 |
| Class 2C, Minor Diameter | Min | 0.3594 | 0.4570 | 0.5371 | 0.6615 | 0.7509 | 0.8753 | 0.9998 | 1.0719 |
| Class 3C, Minor Diameter | Min | 0.3704 | 0.4693 | 0.5511 | 0.6758 | 0.7664 | 0.8912 | 1.0159 | 1.0896 |
| Class 4C, Minor Diameter | Min | 0.3731 | 0.4723 | 0.5546 | 0.6794 | 0.7703 | 0.8951 | 1.0199 | 1.0940 |
| Class 2C, Pitch Diameter | Max | 0.4443 | 0.5562 | 0.6598 | 0.7842 | 0.8920 | 1.0165 | 1.1411 | 1.2406 |
| { Min | 0.4306 | 0.5408 | 0.6424 | 0.7663 | 0.8726 | 0.9967 | 1.1210 | 1.2186 | 1.3429 |
| Class 3C, Pitch Diameter | { Max | 0.4458 | 0.5578 | 0.6615 | 0.7861 | 0.8940 | 1.0186 | 1.1433 | 1.2430 |
| Class 4C, Pitch Diameter | { Min | 0.4394 | 0.5506 | 0.6534 | 0.7778 | 0.8849 | 1.0094 | 1.1339 | 1.2327 |
| Class 4C, Pitch Diameter | { Max | 0.4472 | 0.5593 | 0.6632 | 0.7880 | 0.8960 | 1.0208 | 1.1455 | 1.2453 |
| Class 4C, Pitch Diameter | { Min | 0.4426 | 0.5542 | 0.6574 | 0.7820 | 0.8895 | 1.0142 | 1.1388 | 1.2380 |
| Classes 2C, 3C, and 4C, Major Diameter | Min | 0.5007 | 0.6258 | 0.7509 | 0.8759 | 1.0010 | 1.1261 | 1.2511 | 1.3762 |
| Classes 2C and 3C, Major Diameter | Max | 0.5032 | 0.6286 | 0.7539 | 0.8792 | 1.0045 | 1.1298 | 1.2550 | 1.3803 |
| Class 4C, Major Diameter | Max | 0.5021 | 0.6274 | 0.7526 | 0.8778 | 1.0030 | 1.1282 | 1.2533 | 1.3785 |
| Classes 2C, 3C, and 4C, Minor Diameter | { Min | 0.4100 | 0.5125 | 0.6000 | 0.7250 | 0.8200 | 0.9450 | 1.0700 | 1.1500 |
| { Max | 0.04150 | 0.5187 | 0.6083 | 0.7333 | 0.8300 | 0.9550 | 1.0800 | 1.1625 | 1.2875 |
| Class 2C, Pitch Diameter | Min | 0.4500 | 0.5625 | 0.6667 | 0.7917 | 0.9000 | 1.0250 | 1.1500 | 1.2500 |
| { Max | 0.4637 | 0.5779 | 0.6841 | 0.8096 | 0.9194 | 1.0448 | 1.1701 | 1.2720 | 1.3973 |
| Class 3C, Pitch Diameter | Min | 0.4500 | 0.5625 | 0.6667 | 0.7917 | 0.9000 | 1.0250 | 1.1500 | 1.2500 |
| { Max | 0.4564 | 0.5697 | 0.6748 | 0.8000 | 0.9091 | 1.0342 | 1.1594 | 1.2603 | 1.3854 |
| Class 4C, Pitch Diameter | { Min | 0.4500 | 0.5625 | 0.6667 | 0.7917 | 0.9000 | 1.0250 | 1.1500 | 1.2500 |
| { Max | 0.4546 | 0.5676 | 0.6725 | 0.7977 | 0.9065 | 1.0316 | 1.1567 | 1.2573 | 1.3824 |

Table 2. Keyway Dimensions and Tolerances for Metric Square and Rectangular Parallel Keys ANSI/ASME B18.25 JM-1996 (Withdrawn)

| Key size <i>b</i> × <i>h</i> (mm) | Basic Size ^c | Width. | | | | | | | | | | Depth | | | | Radius, <i>r</i> | |
|---|----------------------------|--|------------------|--------------------|--------------------|------------------|------------------|--------------|------------------|------------------|------------------|---------------------------------|-------------------------------|---------------|----------------|---------------------|--|
| | | Tolerance ^a and Resulting Fits ^b | | | | | Keyway | | | | | Shaft, <i>t</i> ₁ | Hub, <i>t</i> ₂ | Basic Size | Toler- ance | | |
| | | Normal Fit | | Close Fit | | Shaft and Hub | H9 | Fit | D10 | Hub | Basic Size | | | | | | |
| 2 × 2 | 2 | -0.004 -0.029 | 0.010L 0.029T | +0.0125 -0.0125 | 0.0265L 0.0125T | -0.006 0.031T | 0.008L 0T | +0.025 0T | 0.039L +0.020 | +0.060 0.020L | 0.074L 0.020L | 1.2 1.8 | 1.4 1.8 | +0.1 0 | 0.08 0.08 | 0.16 | |
| 3 × 3 | 3 | -0.030 | 0.030T | +0.0150 -0.0150 | 0.033L 0.015T | -0.012 -0.042 | 0.006L 0T | +0.030 0T | 0.048L +0.030 | +0.078 0.030L | 0.096L 0.030L | 2.5 3 | 1.4 2.8 | +0.1 0 | 0.16 0.16 | 0.25 | |
| 4 × 4 | 4 | | | | | | | | | | | | | | | | |
| 5 × 3 | 5 | 0 -0.030 | 0.018L 0.030T | +0.0150 -0.0150 | 0.033L 0.015T | -0.012 -0.042 | 0.006L 0T | +0.030 0T | 0.048L +0.030 | +0.078 0.030L | 0.096L 0.030L | 2.5 3.5 | 1.4 2.8 | +0.1 0 | 0.16 0.16 | 0.25 | |
| 5 × 5 | 6 | | | | | | | | | | | | | | | | |
| 6 × 4 | 6 | | | | | | | | | | | | | | | | |
| 6 × 6 | 6 | | | | | | | | | | | | | | | | |
| 8 × 5 | 8 | | | | | | | | | | | | | | | | |
| 8 × 7 | 8 | 0 -0.036 | 0.022L 0.036T | +0.0180 -0.0180 | 0.040L 0.018T | -0.015 -0.051 | 0.007L 0.051T | +0.036 0T | 0.058L +0.040 | +0.098 0.040L | 0.120L 0.040L | 4 3.5 | +0.2 +0.1 | 3.3 2.8 | +0.1 +0.1 | | |
| 10 × 6 | 10 | | | | | | | | | | | | | | | | |
| 10 × 8 | 10 | | | | | | | | | | | | | | | | |
| 12 × 6 | 12 | | | | | | | | | | | | | | | | |
| 12 × 8 | 12 | | | | | | | | | | | | | | | | |
| 14 × 6 | 14 | 0 -0.043 | 0.027L 0.043T | +0.0215 -0.0215 | 0.0485L 0.0215T | -0.018 -0.061 | 0.009L 0.061T | +0.043 0T | 0.070L +0.050 | +0.120 0.050L | 0.147L 0.050L | 3.5 5.5 | +0.1 0 | 2.8 3.8 | +0.1 +0.2 | 0.25 | |
| 14 × 9 | 14 | | | | | | | | | | | | | | | | |
| 16 × 7 | 16 | | | | | | | | | | | | | | | | |
| 16 × 10 | 16 | | | | | | | | | | | | | | | | |
| 18 × 7 | 18 | | | | | | | | | | | | | | | | |
| 18 × 11 | 18 | | | | | | | | | | | | | | | | |

Footnote c
marker added.
(Footnote on
next page.)

METRIC KEYS AND KEYWAYS

2543

0.6 corrected (was 0.06); also
footnote c marker added

Table 2. (Continued) Keyway Dimensions and Tolerances for Metric Square and Rectangular Parallel Keys ANSI/ASME B18.25.1M-1996 (Withdrawn)

| Key size $b \times h$ (mm) | Basic Size ^c | Width. | | | | | | | | | | Keyway | | | | | | |
|----------------------------------|----------------------------|--|--------|---------------|--------|--------|--------|--------|--------|--------|--------|--------|-----|------------------|------------------|----------------|---------------|----------------|
| | | Tolerance ^a and Resulting Fits ^b | | | | | Shaft | | | | | Hub | | | | Radius, r | | |
| | | Normal Fit | | Shaft and Hub | | P9 | Fit | | H9 | Fit | | D10 | Fit | | Basic Size | Toler- ance | Basic Size | Toler- ance |
| N9 | Fit | Shaft | Hub | JS9 | Fit | P9 | Fit | 0T | 0 | 0T | 0 | 0T | 0T | 0T | 5 | 3.3 | 7.5 | 4.9 |
| 20 × 8 | 20 | -0.052 | 0.033L | +0.026 | 0.059L | -0.022 | 0.011L | +0.052 | 0.085L | +0.149 | 0.182L | 9 | 5.5 | 3.8 | 5.4 | 3.8 | 5.4 | |
| 20 × 12 | 20 | -0.052 | 0.052T | -0.026 | 0.026T | -0.074 | 0.074T | 0 | 0T | +0.065 | 0.065L | 9 | 5.5 | 3.8 | 5.4 | 3.8 | 5.4 | |
| 22 × 9 | 22 | 0 | -0.052 | 0.033L | +0.026 | 0.059L | -0.022 | 0.011L | -0.074 | 0.074T | 0 | 0T | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 × 14 | 22 | 0 | -0.052 | 0.052T | -0.026 | 0.026T | -0.074 | 0.074T | 0 | 0T | +0.065 | 0.065L | 9 | 0 | +0.2 | 0 | +0.2 | 0 |
| 25 × 9 | 25 | 0 | -0.052 | 0.033L | +0.026 | 0.059L | -0.022 | 0.011L | -0.074 | 0.074T | 0 | 0T | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 × 14 | 25 | 0 | -0.052 | 0.052T | -0.026 | 0.026T | -0.074 | 0.074T | 0 | 0T | +0.065 | 0.065L | 9 | 0 | +0.2 | 0 | +0.2 | 0 |
| 28 × 10 | 28 | 0 | -0.052 | 0.033L | +0.026 | 0.059L | -0.022 | 0.011L | -0.074 | 0.074T | 0 | 0T | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 × 16 | 28 | 0 | -0.052 | 0.052T | -0.026 | 0.026T | -0.074 | 0.074T | 0 | 0T | +0.065 | 0.065L | 9 | 0 | +0.2 | 0 | +0.2 | 0 |
| 32 × 11 | 32 | 0 | -0.052 | 0.033L | +0.026 | 0.059L | -0.022 | 0.011L | -0.074 | 0.074T | 0 | 0T | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 × 18 | 32 | 0 | -0.052 | 0.052T | -0.026 | 0.026T | -0.074 | 0.074T | 0 | 0T | +0.065 | 0.065L | 9 | 0 | +0.2 | 0 | +0.2 | 0 |
| 36 × 12 | 36 | 0 | -0.062 | 0.039L | +0.031 | 0.070L | -0.026 | 0.013L | +0.062 | 0.101L | +0.180 | 0.219L | 10 | 7.5 ^c | 7.5 ^c | 10 | 7.4 | 7.4 |
| 36 × 20 | 36 | 0 | -0.062 | 0.062T | -0.031 | 0.031T | -0.088 | 0.088T | 0 | 0T | +0.080 | 0.080L | 12 | 11 ^c | 11 ^c | 12 | 8.4 | 8.4 |
| 40 × 22 | 40 | 0 | -0.062 | 0.039L | +0.031 | 0.070L | -0.026 | 0.013L | +0.062 | 0.101L | +0.180 | 0.219L | 13 | 12 | 12 | 13 | 9.4 | 9.4 |
| 45 × 25 | 45 | 0 | -0.087 | 0.087T | -0.037 | 0.037T | -0.077 | 0.077T | -0.106 | 0.106T | +0.074 | 0.120L | 15 | 15 | 15 | 15 | 10.4 | 10.4 |
| 50 × 28 | 50 | 0 | -0.087 | 0.087T | -0.037 | 0.037T | -0.077 | 0.077T | -0.106 | 0.106T | +0.074 | 0.120L | 17 | 17 | 17 | 17 | 11.4 | 11.4 |
| 56 × 32 | 56 | 0 | -0.074 | 0.046L | +0.037 | 0.083L | -0.032 | 0.014L | +0.074 | 0.120L | +0.220 | 0.266L | 20 | +0.3 | 12.4 | 20 | +0.3 | 12.4 |
| 63 × 32 | 63 | 0 | -0.074 | 0.074T | -0.037 | 0.037T | -0.037 | 0.037T | -0.106 | 0.106T | 0 | 0T | 0 | 0 | 0 | 0 | 12.4 | 12.4 |
| 70 × 36 | 70 | 0 | -0.087 | 0.087T | -0.037 | 0.037T | -0.077 | 0.077T | -0.106 | 0.106T | +0.074 | 0.120L | 22 | 22 | 22 | 22 | 14.4 | 14.4 |
| 80 × 40 | 80 | 0 | -0.087 | 0.087T | -0.037 | 0.037T | -0.077 | 0.077T | -0.106 | 0.106T | +0.074 | 0.120L | 25 | 25 | 25 | 25 | 15.4 | 15.4 |
| 90 × 45 | 90 | 0 | -0.087 | 0.087T | -0.037 | 0.037T | -0.077 | 0.077T | -0.106 | 0.106T | +0.087 | 0.139L | 28 | 28 | 28 | 28 | 17.4 | 17.4 |
| 100 × 50 | 100 | 0 | -0.087 | 0.087T | -0.037 | 0.037T | -0.077 | 0.077T | -0.106 | 0.106T | +0.087 | 0.139L | 31 | 31 | 31 | 31 | 20 | 20 |

Footnote c revised.

Footnote c marker added.

^a Some of the tolerances are expressed as plus-plus. See *Tolerances* on page 2539 for more information.

^b Resulting fits: L indicates a clearance between the key and keyway; T indicates an interference between the key and keyway.

^c Values changed for accuracy from that given in ANSI/ASME B18.25.1M-1996 (Withdrawn).

Table 5. Units Outside SI, Accepted for Use with SI

| Name | Symbol | Value in SI Units |
|--------------------------|---------|---|
| minute | min | 1 min = 60 s |
| hour | h | 1 h = 60 min = 3600 s |
| day | d | 1 d = 24 h = 1440 min = 86400 s |
| liter | L | 1 L = 1 dm ³ = 10 ⁻³ m ³ |
| metric ton | t | 1 t = 10 ³ kg = 2205 lb |
| bel | B | 1 B = 10 dB |
| degree (angle) | ° | 1° = π/180 rad |
| minute (angle) | ' | 1' = (1/60)° = (π/10800) rad |
| second (angle) | " | 1" = (1/60)' = (π/6480000) rad |
| electron volt | eV | 1 eV = 1.60218 × 10 ⁻¹⁹ J |
| unified atomic mass unit | Da or u | 1 u = 1.66054 × 10 ⁻²⁷ kg |
| astronomical unit | au | 1 au = 1.49598 × 10 ¹¹ m |
| nautical mile | nmi | 1 nmi = 1852 m |
| knot | kn | 1 kn = 1 nmi·h ⁻¹ = 0.514444 m·s ⁻¹ |
| are | a | 1 a = 100 m ² |
| hectare | ha | 1 ha = 100 a = 10 ⁴ m ² |
| bar | bar | 1 bar = 10 ² kPa = 10 ⁵ Pa |
| ångström | Å | 1 Å = 0.1 nm = 10 ⁻¹⁰ m |
| curie | Ci | 1 Ci = 3.7 × 10 ¹⁰ Bq |
| roentgen | R | 1 R = 2.58 × 10 ⁻⁴ C·kg ⁻¹ |
| rad | rad | 1 rad = 10 ⁻² Gy |
| rem | rem | 1 rem = 10 ² Sv |

Dot/
decimal
placement
corrected in
2.58 in
roentgen
equation.


Table 6. SI Prefixes

| Factor | Name | Symbol | Factor | Name | Symbol |
|------------------|-------|--------|-------------------|-------|--------|
| 10 ¹ | deca | da | 10 ⁻¹ | deci | d |
| 10 ² | hecto | h | 10 ⁻² | centi | c |
| 10 ³ | kilo | k | 10 ⁻³ | milli | m |
| 10 ⁶ | mega | M | 10 ⁻⁶ | micro | μ |
| 10 ⁹ | giga | G | 10 ⁻⁹ | nano | n |
| 10 ¹² | tera | T | 10 ⁻¹² | pico | p |
| 10 ¹⁵ | peta | P | 10 ⁻¹⁵ | femto | f |
| 10 ¹⁸ | exa | E | 10 ⁻¹⁸ | atto | a |

Standard of Length and the US Customary Unit System

Among all units of measure, the history of standard of length traces a clear path from the less scientific approach of physical object standards used in past centuries to the today's precise standards, based on physical constants on an atomic level.

The primary Imperial yard was set by the British Weights and Measures Act of 1824. But it was partially destroyed in a fire in 1834, and replaced by a new standard, made of an alloy of copper, tin, and zinc. Between 1845 and 1855, forty copies of the Imperial yard were cast. Bronze yard No. 11 went to the United States, an exact copy of the British Imperial yard, in both form and material.

By an Act of Congress, in 1866, the US legally recognized the meter as a standard of length equal to 39/39.37 = 0.9144 yard; for commercial purposes, 1 meter = 39.37 inches.