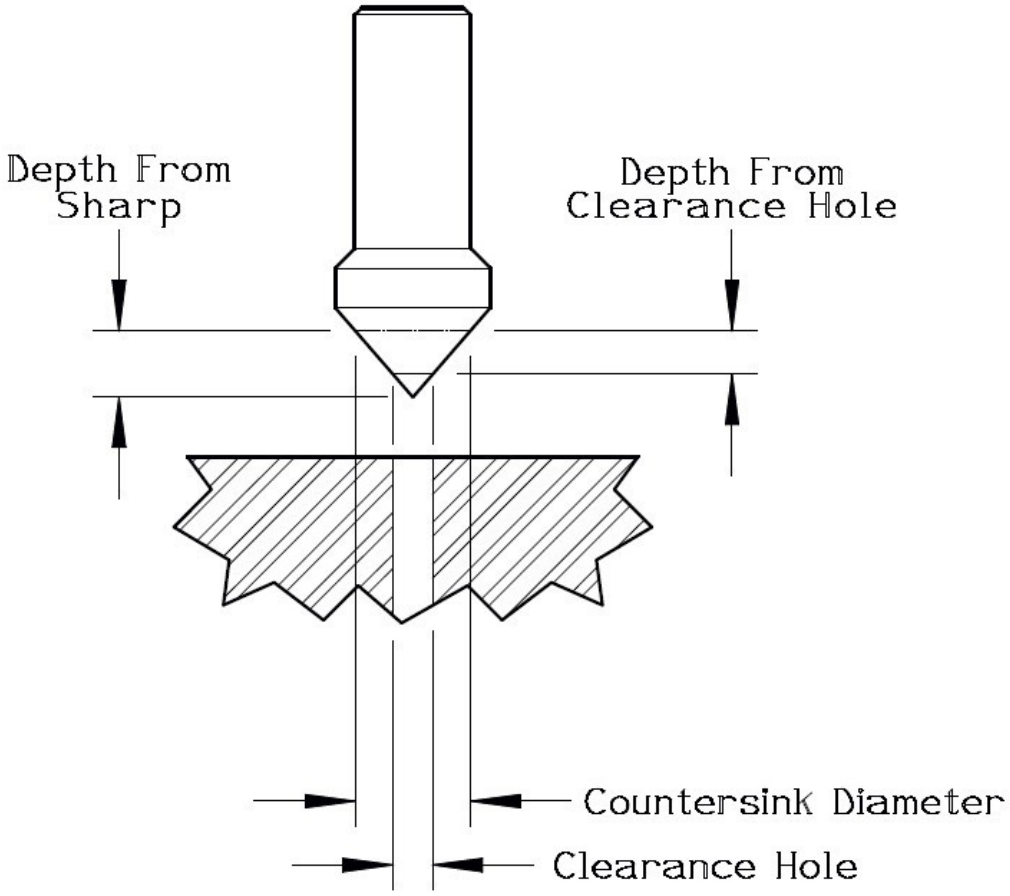
Countersunk Fastener Hole Considerations

Countersunk fasteners pose a special challenge to the designer. The nature of the head requires that tight tolerances by applied to prevent unwanted bending forces from weakening the joint. It differs from a normal screw in that the head **will** self-center on the countersink and **not** provide a radial position allowance at assembly. The first screw tightened in the assembly will establish the relative *pivot position* of the components being assembled. The second screw tightened will establish the *rotation about the pivot* that aligns the components. Good design practice suggests that these positions be established on the engineering drawing and assembly instructions to provide consistent results. Tertiary screws will try to pull the components out of alignment, but are usually overpowered by the #1 and #2 attachment forces.

Metric flat head screws have a 90° included countersink angle. Inch-sized flat head screws have either a 100° (usually limited to aerospace applications) or 82° included countersink angle. Socket or Torx Head screws have a larger countersink diameter than common (straight slot, Phillips head, or Robertson square drive) screws. These distinctions need to be kept clear throughout the design process.

Design & Assembly Considerations:

The strength of a flat head screw's connection lies in the contact area between the countersunk surface of the retained part and the head of the screw. Therefore, the clearance hole for the screw should be the minimum that the manufacturing process can reasonably support. This suggests that, whenever possible, screw holes for countersunk fasteners should be *match drilled*. This is not always possible, but it is one fairly simple alignment solution.



Countersink/Hole Relative Geometry

In most instances, the reason to use flat head fasteners is to provide a smooth surface to the assembled parts. The designer is concerned that the head of the fastener **not** protrude above the surface of the parts (or *stand proud* in traditional terms). The machinist or mechanic making the hole rarely has a *stop* to control the diameter of the resulting hole (and countersinks should normally be made using a drill press or other orientation and depth controlling device). [There used to be a type of piloted countersink with a *stop collar* that could be adjusted to control the depth/diameter of a countersink, but they have not been readily available for many years now. They provided reasonable control for someone driving a countersink with a hand drill.]

Design Tolerance Considerations: In the charts that follow, the *Theoretical Sharp Diameter* represents the diameter of countersink that will place *maximum material condition* screwhead flush to the surface of a flat part. This is the nominal diameter of the countersink for the fastener. The tolerance should be identified (either by dimensional tolerance, in a general note, or hole preparation specification) as a +.XXX/-0 value appropriate to the method of manufacture whenever a flush or sub-flush condition is needed in the assembly. Generally speaking, such a tolerance should be: +.020/-.000 (+.5/-0 mm) for a CNC machine tool, +.030/-.000 (+.75/-0 mm) for a manual milling machine, and +.050/-.000 (+1.25/-0 mm) for a drill press. If tighter tolerances are required, a master countersink gage (i.e. a blank manufactured to the *maximum material condition* of the screwhead) should be provided to the shop along with a specific maximum depth below the surface of the gage in a properly countersunk hole. Set-ups made in this manner can control depths to within .005 (.13 mm) on almost any machine tool. It is quite difficult to measure the countersunk hole's edge to determine its diameter, so a gage *depth below surface* is a more accurate and repeatable means of establishing the true value of a countersunk hole's form.

Manufacturing Tolerance Considerations: Holes that need to be accurately drilled should **always** be based on a center-drilled or spot-drilled location. The chisel edge at the center of a drill bit will want to *walk* when it hits the surface of the part to be drilled. A center- or spot-drilled starter hole lets the flanks of the drill bit (more accurately ground in most instances) begin the cut and prevent the central chisel edge from contacting the part until at least one full diameter of the bit is bearing on the hole making for a more accurately placed (and sized) hole. In most materials (titanium and certain ceramics being the main exceptions) a drill will create a slightly elliptical hole that runs up to .006 (.15 mm) larger than the size of the drill bit in holes 500 (2.5 mm) and smaller. [Titanium and certain ceramics are strong and abrasive enough to compress the drill bit and create a slightly undersize hole.]

Basic Equations: If Θ is the included angle of the countersink, Ø is the theoretical sharp diameter of the countersunk hole, ø is the diameter of the clearance hole, and D is the depth to which the countersink must move to create the desired (Θ) countersunk diameter; then:

$$D = Ø/(2*\tan(Θ/2))$$ for the Depth from Sharp Point of Countersink, and

$$D = (Ø-ø)/(2*\tan(Θ/2))$$ for the Depth from Clearance Hole Diameter.

The rest of the information in the tables comes from standard (ASME/ANSI and ISO) specifications and practices.

90° Countersunk Hole Chart (Metric):

90° Metric Flat Head Screw				
5mm Depth per 10 mm of Countersink Diameter				
Screw Size:	Clearance Hole Diameter:	Theoretical Sharp Diameter:	Depth from Sharp Point of CSink:	Depth from Clearance Hole:
M2	2.2 mm	4.4 mm	2.2 mm	1.1 mm
M2.5	2.7 mm	5.5 mm	2.75 mm	1.4 mm
M3	3.2 mm	6.3 mm	3.15 mm	1.55 mm
M3.5	3.8 mm	8.2 mm	4.1 mm	2.2 mm
M4	4.4 mm	9.4 mm	4.7 mm	2.5 mm
M5	5.5 mm	10.4 mm	5.2 mm	2.45 mm
M6	6.5 mm	12.6 mm	6.3 mm	3.05 mm
M8	8.5 mm	17.3 mm	8.65 mm	4.4 mm
M10	10.5 mm	20 mm	10 mm	4.75 mm

90° Metric Socket Flat Head Cap Screw				
5mm Depth per 10 mm of Countersink Diameter				
Screw Size:	Clearance Hole Diameter:	Theoretical Sharp Diameter:	Depth from Sharp Point of CSink:	Depth from Clearance Hole:
M3	3.2 mm	6.72 mm	3.36 mm	1.76 mm
M4	4.4 mm	8.96 mm	4.48 mm	2.28 mm
M5	5.5 mm	11.2 mm	5.6 mm	2.85 mm
M6	6.5 mm	13.44 mm	6.72 mm	3.47 mm
M8	8.5 mm	17.92 mm	8.96 mm	4.71 mm
M10	10.5 mm	22.4 mm	11.2 mm	5.95 mm
M12	12.5 mm	26.88 mm	13.44 mm	7.19 mm
M16	16.5 mm	33.6 mm	16.8 mm	8.55 mm
M20	21 mm	40.32 mm	20.16 mm	9.66 mm

82° Countersunk Hole Chart (Inch):

82° Flat Head Screw				
.575 Depth per 1.000 inch of Countersink Diameter				
Screw Size:	Clearance Hole Diameter:	Theoretical Sharp Diameter:	Depth from Sharp Point of CSink:	Depth from Clearance Hole:
#0	.063	.119	.068	.032
#1	.081	.146	.084	.037
#2	.089	.172	.099	.048
#3	.102	.199	.114	.056
#4	.116	.225	.129	.063
#5	.129	.252	.145	.071
#6	.141	.279	.160	.080
#8	.166	.332	.191	.095
#10	.194	.385	.221	.110
#12	.219	.438	.252	.126
.2500	.257	.507	.292	.144
.3125	.316	.635	.365	.183
.3750	.377	.762	.438	.221
.4375	.453	.812	.467	.206
.5000	.516	.875	.503	.207
.6525	.578	1.000	.575	.243
.6250	.641	1.125	.647	.279
.7500	.766	1.375	.791	.350
.8750	.891	1.625	.934	.422
1.0000	1.016	1.875	1.078	.494
1.1250	1.141	2.062	1.186	.530
1.2500	1.266	2.312	1.329	.602
1.3750	1.391	2.562	1.473	.674
1.5000	1.516	2.812	1.617	.745

82° Countersunk Hole Chart (Inch – Continued):

82° Socket Flat Head Cap Screw				
.575 Depth per 1.000 inch of Countersink Diameter				
Screw Size:	Clearance Hole Diameter:	Theoretical Sharp Diameter:	Depth from Sharp Point of CSink:	Depth from Clearance Hole:
#0	.063	.138	.079	.043
#1	.081	.168	.097	.050
#2	.089	.197	.113	.062
#3	.102	.226	.130	.072
#4	.116	.255	.147	.080
#5	.129	.281	.162	.088
#6	.141	.307	.177	.096
#8	.166	.359	.206	.111
#10	.194	.411	.236	.125
#12	.219	.438	.252	.117
.2500	.257	.531	.305	.158
.3125	.316	.656	.377	.196
.3750	.377	.781	.449	.232
.4375	.453	.844	.485	.225
.5000	.516	.938	.539	.243
.6250	.641	1.188	.683	.315
.7500	.766	1.438	.827	.387
.8750	.891	1.688	.971	.458
1.0000	1.016	1.938	1.114	.530
1.1250	1.141	2.188	1.258	.602
1.2500	1.266	2.438	1.402	.674
1.3750	1.391	2.688	1.546	.746
1.5000	1.516	2.938	1.689	.818

100° Countersunk Hole Chart (Inch):

100° Flat Head Screw				
.420 Depth per 1.000 inch of Countersink Diameter				
Screw Size:	Clearance Hole Diameter:	Theoretical Sharp Diameter:	Depth from Sharp Point of CSink:	Depth from Clearance Hole:
#0	.063	.119	.050	.024
#1	.081	.146	.061	.027
#2	.089	.172	.072	.035
#3	.102	.199	.083	.041
#4	.116	.225	.094	.046
#5	.129	.252	.106	.052
#6	.141	.279	.117	.058
#8	.166	.332	.139	.070
#10	.194	.385	.162	.080
#12	.219	.438	.184	.088
.2500	.257	.507	.213	.105
.3125	.316	.635	.266	.134
.3750	.377	.762	.320	.162
.4375	.453	.812	.341	.151
.5000	.516	.875	.367	.151
.6525	.578	1.000	.420	.177
.6250	.641	1.125	.472	.203
.7500	.766	1.375	.577	.256
.8750	.891	1.625	.682	.308
1.0000	1.016	1.875	.787	.361
1.1250	1.141	2.062	.865	.387
1.2500	1.266	2.312	.970	.439
1.3750	1.391	2.562	1.075	.491
1.5000	1.516	2.812	1.180	.544

