Introduction to Taps and Dies

- Taps come individually or in sets. They also come in five basic types which define the cutting flute configuration. This is one area where buying the more expensive version is the right strategy – there are a ton of easily broken taps in the market to avoid.
- A straight tap is the most common and they come in “plug” “starting” and “bottoming” verities which only defines how far the cutting part of the flute extends toward the tip. They look like this:

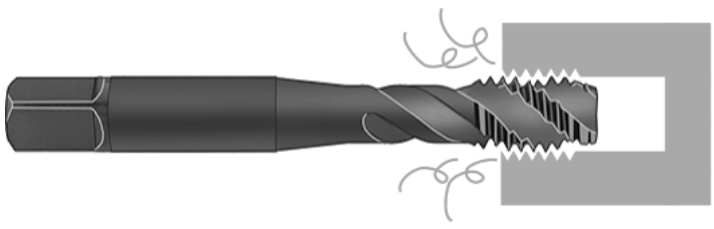
For Starting Threads

For Through-Hole Threading

For Closed-End Hole Threading

- All three types leave the machined material in the hole to clog up in the straight side flutes. This means you have to “peck” – rotate forward, then back to break the chip, then forward again, and eventually the flutes will fill with chips and the tap will break unless you remove it completely and clean the tap and hole before going on. If you tap to the bottom of a blind hole, you will tap most of the way with a plug tap, then remove that, and do the remainder of the threading to the bottom of the hole with a bottoming tap. This style tap is very brittle and if you plan to drive the tap with a machine, buy only the highest quality versions such as Widia (from McMaster), Hertel, OSG, Guhring (from MSCDirect), and Morse (from MariTool) are my go-to choices.
- Spiral point taps are designed to drive the chip formed by the cutting action forward. They are only appropriate for through holes. They look like this:

- They are about twice the strength of the straight taps and my choice for machine tapping. I will often drill the hole through just to be able to use a spiral point tap even though I’m only treading part way down the hole.
- Spiral flute taps are designed to extract the chip being cut backward and out of the hole, but these taps are much easier to break than any of the others, and thus only appropriate for machine tapping with some kind of torque limiting device (loose in the chuck or with a tapping head). They look like this:



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- Each tap size has a corresponding pilot drill size. After drilling the pilot hole, be sure to chamfer the hole to let the tap guide its way into the hole. In metric, the pilot drill size is often not a standard metric drill bit size, so be sure to use the precise pilot drill with the tap or you will break the tap. In SAE (Imperial), the pilot hole is often a letter sized drill bit. I have a wall chart that shows all the threads, and what size drill bit is appropriate, and I refer to it constantly.
- There's one other type of tap, called "thread forming" which doesn't cut the thread but instead molds the threads as it's wound into the hole. I have had success with these in plastics – not metals as they require coolant, or they overheat and gall/weld to the material. These taps look like this:

- Proper pilot hole drilling and chamfering the hole prior to tapping is important. Be sure to use the proper pilot hole drill size. Drill sizes for imperial and metric threads are shown in tables that follow at the end of this document.
- Imperial screws with countersink require an 82° countersink profile. Metric screws with countersink require a 90° countersink profile. Spot drills for turning between centers on a lathe require a 60° included angle profile.
- Stainless steel and hard alloy steels should be drilled with 135° pointed drill bits, preferably made of Cobalt or Carbide rather than HSS.
- Spot drills should have an angle slightly larger than the point on the pilot hole drill. For 118° point drills, use a spot drill with 120° face angle. Similarly, with 135° point drills, use a spot drill with a 140° face angle.

Notes on use:

Taps are brittle and easily broken if not used properly. Keeping the tap precisely aligned to the pilot hole is critically important. If the tap is started crooked, or tilted during the tapping operation, the tap is likely to fracture leaving a section of the broken tap in the hole. These broken tap elements are notoriously difficult to remove.

If forced to hand tap, use a tap guide to keep the tap aligned precisely to the orientation of the pilot hole. Tap guides are available in several forms, and you can make your own on a drill press. Shown below are two commercially available tap guides available for most imperial and metric tap sizes.

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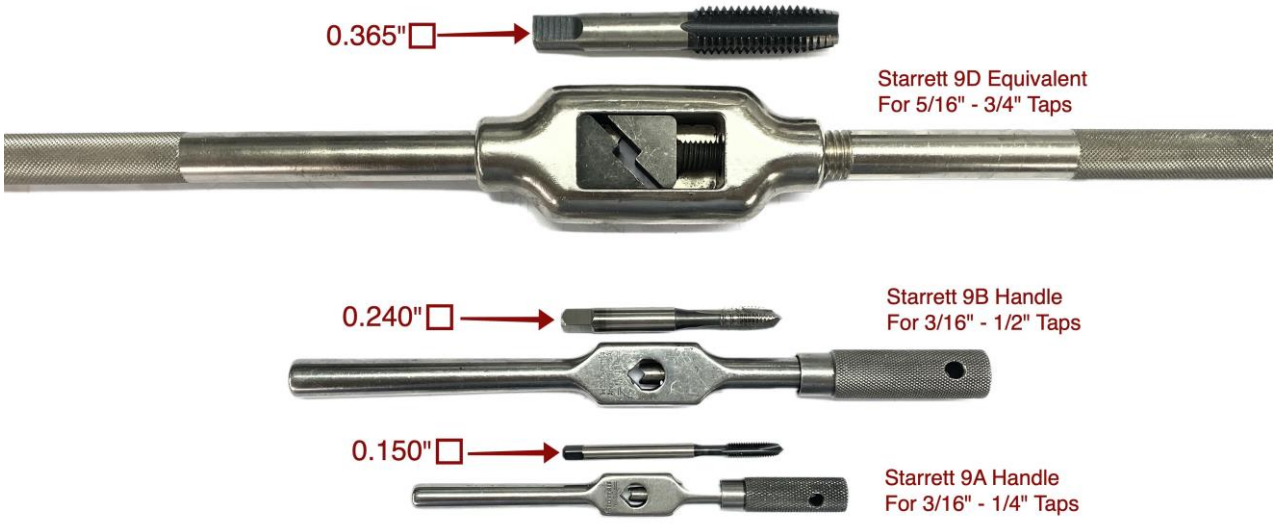
Hand tapping handles are available in two basic configurations, and typically in four different sizes that determine the range of size tap sizes that can be mounted in the handle. The two basic types are shown below, and each type has a range of tap sizes that can be accommodated.

Straight Handle Type	T-Handle Type
	

Commonly, straight handle type tap wrench sizes are identified by the Starrett brand model numbers. The Starrett models are based on the size of the tap which relates to the size of the square end of the tap. Starrett is not the only manufacturer of straight handle types – alternatives are available from several manufacturers. Shown below are the Starrett straight handle type sizes.

Starrett Tap Wrench Sizes	
Model Number	Hand Tap Capacity (inches)
9A	1/16 - 1/4
9B	3/16 - 1/2
9C	1/4 - 5/8
9D	5/16 - 3/4

Shown below are the three most useful straight handle sizes that cover the full range of tap sizes from 1/16 to 3/4-inch tap sizes. The size of the square end of taps are also illustrated.

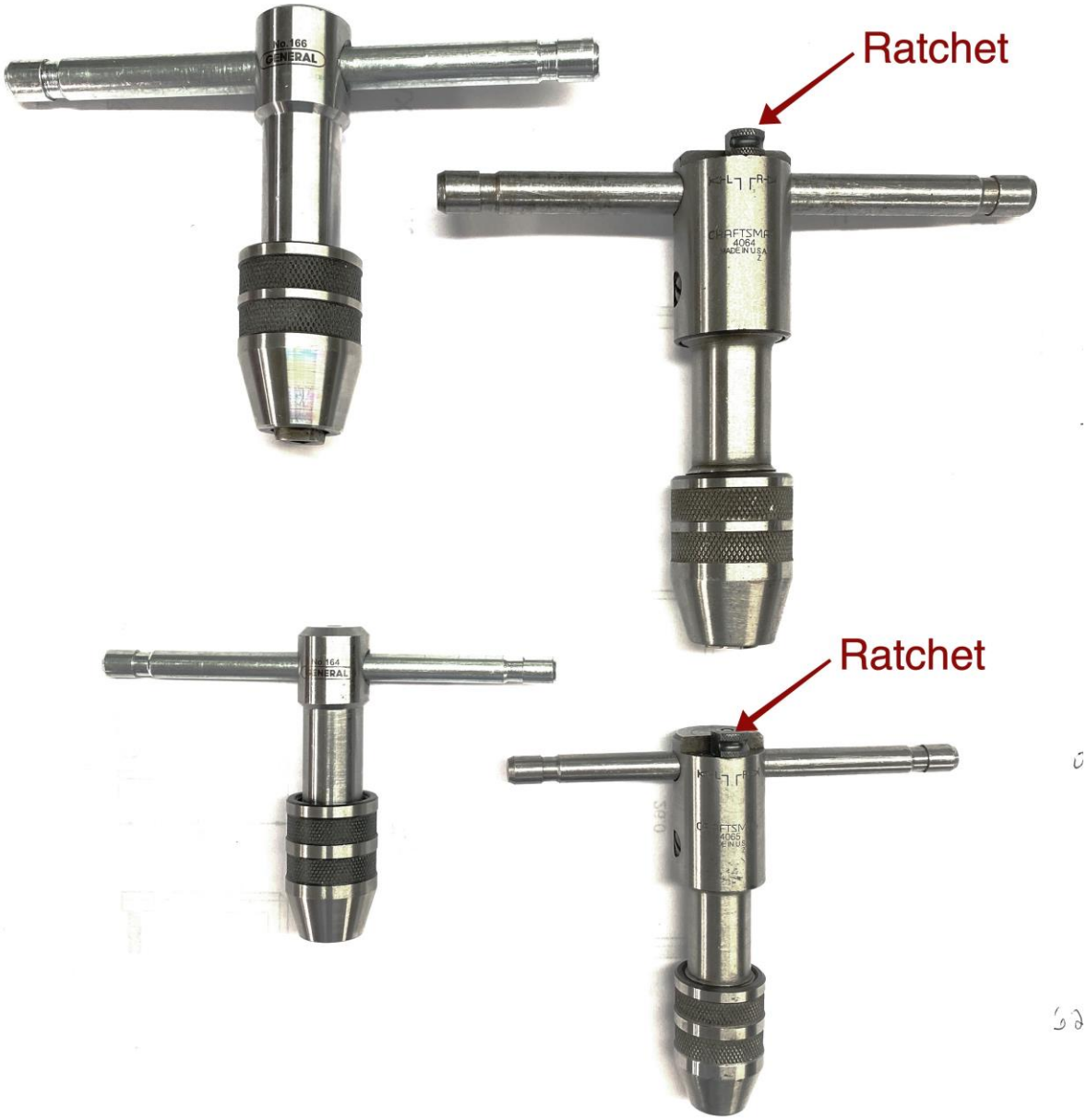


Adjustable straight handle tap wrenches leave the end of the tap shank exposed. Some taps have a center dimple, others have a pointed end as shown below. You can use the pointed tap follower shown above on the taps with the dimple center to guide the tap and keep it vertical.

A spring-loaded tap follower can be used to maintain vertical tap alignment when machine tapping on a mill or drill press. This version of tap follower has a pointed end that is used with taps with a drive center (dimpled hole).

For taps that have a pointed end, another version of the spring-loaded tap follower is available with a reverse point that will fit over the pointed end of the tap. They look like this.

Like their straight-handle counterparts, T-handled tap wrenches are available in a few sizes and two common configurations. The basic version (shown on the right in the photo below) has a direct connection between the T-bar and the chuck that holds the tap. The other version (shown on the right in the photo below) have a ratchet mechanism similar to a socket-set ratchet handle, which can be helpful in situations where full 360° rotation is not possible. The top of the handle has a lever that switches the direction of the ratchet mechanism or to disable it completely.



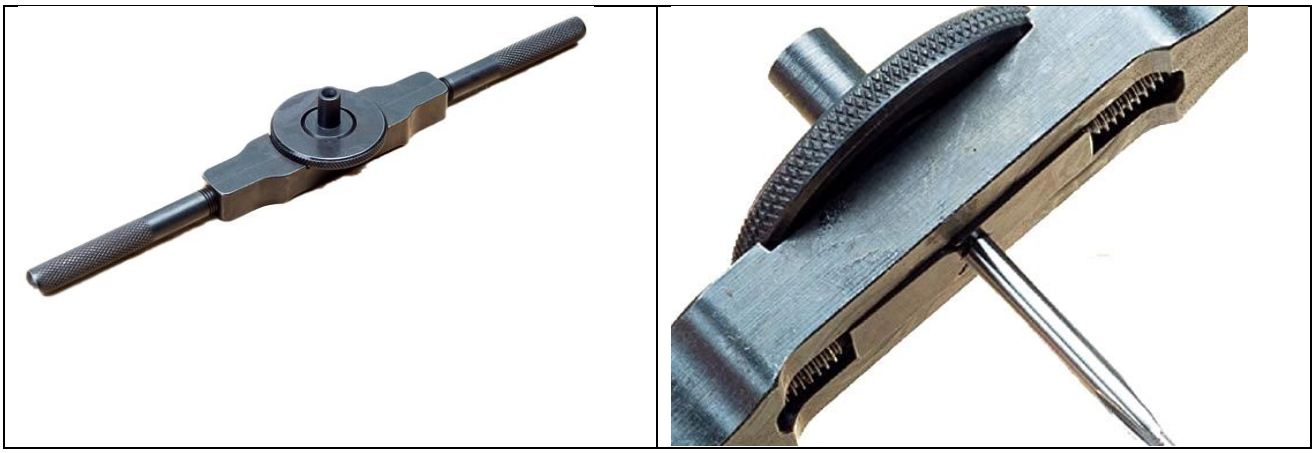
The non-ratcheting T-handled tap wrenches will usually have a drive center (small dimple) in the top of the handle (green arrow below) that is precisely on-center with the chuck that holds the tap. One disadvantage of the T-handle type (compared to the straight-handle variety) when machine tapping is the additional Z-height required.

This drive center can be used in conjunction with a spring-loaded tap follower for machine tapping with a lathe, mill, or drill press as shown below, keeping the tap aligned precisely to the pilot hole.

Some T-handle tap wrenches have a ratchet mechanism similar to a socket-set ratchet handle, which can be helpful in situations where full 360° rotation is not possible, however the ratcheting type rarely have the drive center hole, so check before buying. The image below is typical of the handle-end of a ratcheting version – note the lack of a drive center.

Special tap handles exist for use on a drill press, mill, or lathe tailstock that include a shaft that can be secured in the drill chuck to guide the vertical alignment as shown below is available from Amazon, and a higher precision version is available from Penn Tools.

Shown below is one of my favorite tap handles for use on the milling machine or drill press. It's low profile so it does not take a lot of Z-axis space like the T-handled tap wrenches, and it will automatically center the tap under the tap-follower recess on the back of the wrench. It's available from Northern Machining.



About threading dies.

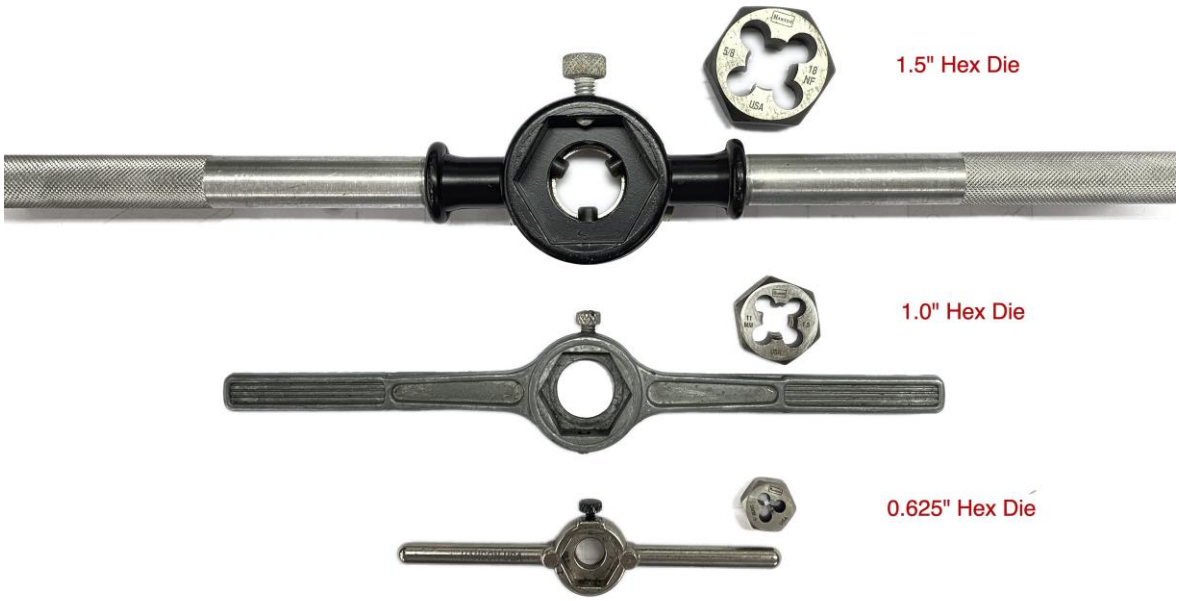
Threading dies are typically available in two types: Hex-shaped dies that are commonly referred to as "re-threading dies", and round dies that are often referred to as "split" or "adjustable" dies. Each type has slightly different attributes.

Typical Hex-Die	Typical Split or Round Die
	

The hex-shaped dies can be used to re-thread or freshen up the threads on an existing bolt or threaded shaft. But in most cases, they can also be used to cut new threads on many materials. The quality of the hex-die will determine whether it can cut new threads in addition to re-threading an existing component. Many hex-dies are poor quality and will struggle or fail to cut new threads, particularly in difficult materials like hardened steel or stainless steel. This is not to say that high quality hex-dies aren’t available, but the most commonly available types are of lower quality.

The handles to hold a threading die are called “die stocks.” They are available in various sizes for both hex and round die types.

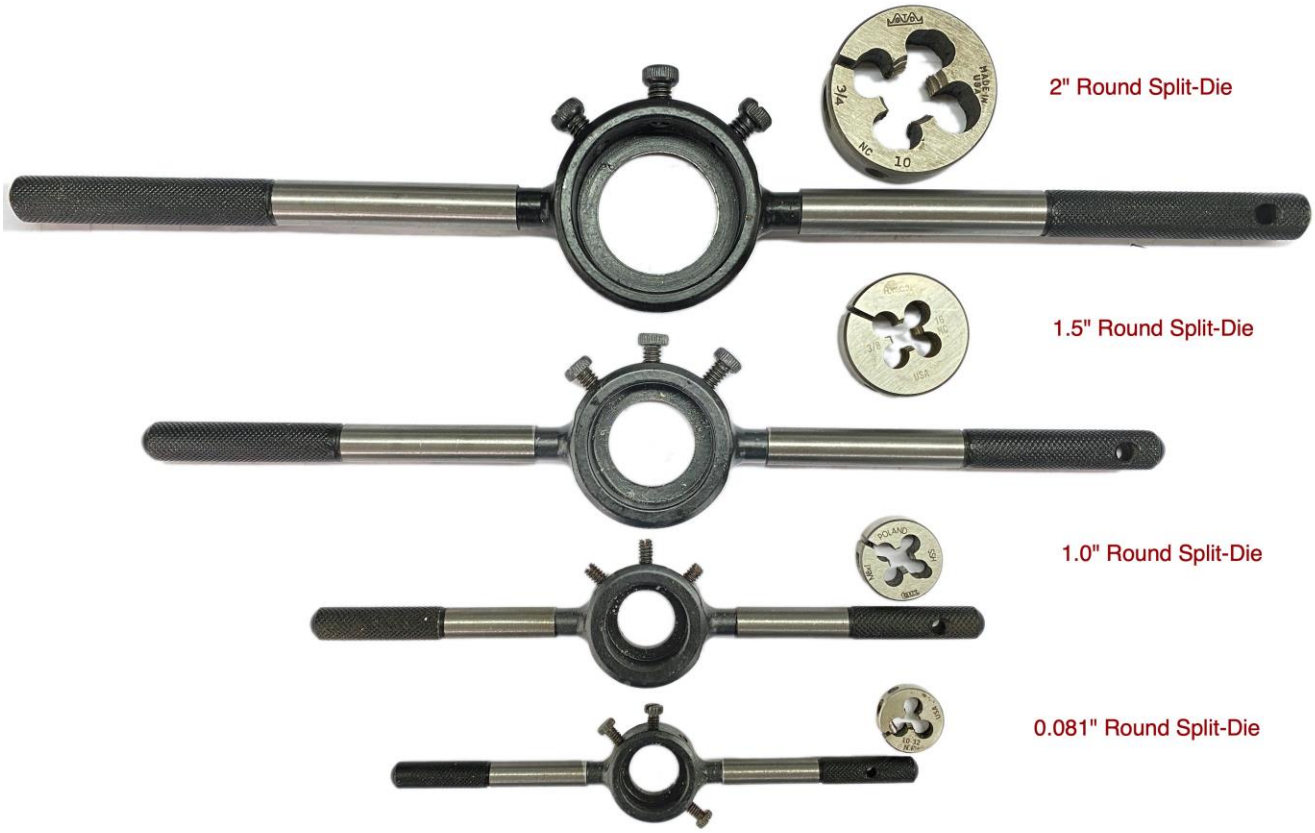
Hex dies generally come in standard sizes as shown below, along with the die stocks that hold them.



Round dies are generally preferred for cutting new threads, and the split-die versions are adjustable over a narrow range. This adjustability is accomplished via a split in the perimeter of the die, and a set screw that can be used to force the die to open slightly, thus producing a slightly larger thread. In my experience, most split-dies are pre-loaded to cut a thread that is slightly smaller than nominal size, but can be adjusted with the set screw to meet most tolerance specifications.

Again, in my experience, the best quality split-dies are capable of threading even the most demanding materials. Split-dies are not typically available as sets for common sizes, so be prepared to buy individual dies as the need arises. Quality split-dies made in Europe and Japan come up on eBay consistently, and this can be an excellent lower-cost source when building your die collection.

Shown below are the common outside diameter sizes of the round or split-die types, along with the die stocks that hold them.



Where to source tap handles and die stocks

Buy new from an industrial supplier like MSCdirect.com, McMaster, Travers Tool, etc. or direct from the manufacturer. Or buy top brands (Starrett, Greenfield, etc.) used for a fraction of new on eBay.

The quality brands for hand tapping are Starrett, Cle-Line, Greenfield, Dormer, and General. Similar versions are available as Asian imports but may or may not have the features for vertical alignment discussed above. For machine tapping, my favorite that requires the least Z-height is the Northern Machining model discussed above, and the spindle tap wrench from Penn Tools.

The die stock set shown immediately above is available from MSCDirect.com – this is not an investment grade set, but has plenty of utility.

Imperial Tap & Clearance Drill Sizes

Tap & Clearance Drill Sizes				Tap Drill				Clearance Drill			
Screw Size	Major Diameter	Threads Per Inch	Minor Diameter	75% Thread for Aluminum, Brass, & Plastics		50% Thread for Steel, Stainless, & Iron		Close Fit		Free Fit	
				Drill Size	Dec. Eq.	Drill Size	Dec. Eq.	Drill Size	Dec. Eq.	Drill Size	Dec. Eq.
0	.0600	80	.0447	3/64	.0469	55	.0520	52	.0635	50	.0700
1	.0730	64	.0538	53	.0595	1/16	.0625	48	.0760	46	.0810
		72	.0560	53	.0595	52	.0635				
2	.0860	56	.0641	50	.0700	49	.0730	43	.0890	41	.0960
		64	.0668	50	.0700	48	.0760				
3	.0990	48	.0734	47	.0785	44	.0860	37	.1040	35	.1100
		56	.0771	45	.0820	43	.0890				
4	.1120	40	.0813	43	.0890	41	.0960	32	.1160	30	.1285
		48	.0864	42	.0935	40	.0980				
5	.125	40	.0943	38	.1015	7/64	.1094	30	.1285	29	.1360
		44	.0971	37	.1040	35	.1100				
6	.138	32	.0997	36	.1065	32	.1160	27	.1440	25	.1495
		40	.1073	33	.1130	31	.1200				
8	.1640	32	.1257	29	.1360	27	.1440	18	.1695	16	.1770
		36	.1299	29	.1360	26	.1470				
10	.1900	24	.1389	25	.1495	20	.1610	9	.1960	7	.2010
		32	.1517	21	.1590	18	.1695				
12	.2160	24	.1649	16	.1770	12	.1890	2	.2210	1	.2280
		28	.1722	14	.1820	10	.1935				
		32	.1777	13	.1850	9	.1960				
1/4	.2500	20	.1887	7	.2010	7/32	.2188	F	.2570	H	.2660
		28	.2062	3	.2130	1	.2280				
		32	.2117	7/32	.2188	1	.2280				
5/16	.3125	18	.2443	F	.2570	J	.2770	P	.3230	Q	.3320
		24	.2614	I	.2720	9/32	.2812				
		32	.2742	9/32	.2812	L	.2900				
3/8	.3750	16	.2983	5/16	.3125	Q	.3320	W	.3860	X	.3970
		24	.3239	Q	.3320	S	.3480				
		32	.3367	11/32	.3438	T	.3580				
7/16	.4375	14	.3499	U	.3680	25/64	.3906	29/64	.4531	15/32	.4687
		20	.3762	25/64	.3906	13/32	.4062				
		28	.3937	Y	.4040	Z	.4130				
1/2	.5000	13	.4056	27/64	.4219	29/64	.4531	33/64	.5156	17/32	.5312
		20	.4387	29/64	.4531	15/32	.4688				
		28	.4562	15/32	.4688	15/32	.4688				
9/16	.5625	12	.4603	31/64	.4844	33/64	.5156	37/64	.5781	19/32	.5938
		18	.4943	33/64	.5156	17/32	.5312				
		24	.5114	33/64	.5156	17/32	.5312				
5/8	.6250	11	.5135	17/32	.5312	9/16	.5625	41/64	.6406	21/32	.6562
		18	.5568	37/64	.5781	19/32	.5938				
		24	.5739	37/64	.5781	19/32	.5938				
11/16	.6875	24	.6364	41/64	.6406	21/32	.6562	45/64	.7031	23/32	.7188
3/4	.7500	10	.6273	21/32	.6562	11/16	.6875	49/64	.7656	25/32	.7812
		16	.6733	11/16	.6875	45/64	.7031				
		20	.6887	45/64	.7031	23/32	.7188				
13/16	.8125	20	.7512	49/64	.7656	25/32	.7812	53/64	.8281	27/32	.8438
7/8	.8750	9	.7387	49/64	.7656	51/64	.7969	57/64	.8906	29/32	.9062
		14	.7874	13/16	.8125	53/64	.8281				
		20	.8137	53/64	.8281	27/32	.8438				
15/16	.9375	20	.8762	57/64	.8906	29/32	.9062	61/64	.9531	31/32	.9688
1	1.000	8	.8466	7/8	.8750	59/64	.9219	1-1/64	1.0156	1-1/32	1.0313
		12	.8978	15/16	.9375	61/64	.9531				
		20	.9387	61/64	.9531	31/32	.9688				

Metric Tap & Clearance Drill Sizes		Tap Drill				Clearance Drill			
		75% Thread for Aluminum, Brass, & Plastics		50% Thread for Steel, Stainless, & Iron		Close Fit		Standard Fit	
Screw Size (mm)	Thread Pitch (mm)	Drill Size (mm)	Closest American Drill	Drill Size (mm)	Closest American Drill	Drill Size (mm)	Closest American Drill	Drill Size (mm)	Closest American Drill
M1.5	0.35	1.15	56	1.25	55	1.60	1/16	1.65	52
M1.6	0.35	1.25	55	1.35	54	1.70	51	1.75	50
M 1.8	0.35	1.45	53	1.55	1/16	1.90	49	2.00	5/64
M 2	0.45	1.55	1/16	1.70	51	2.10	45	2.20	44
	0.40	1.60	52	1.75	50				
M 2.2	0.45	1.75	50	1.90	48	2.30	3/32	2.40	41
M 2.5	0.45	2.05	46	2.20	44	2.65	37	2.75	7/64
M 3	0.60	2.40	41	2.60	37	3.15	1/8	3.30	30
	0.50	2.50	39	2.70	36				
M 3.5	0.60	2.90	32	3.10	31	3.70	27	3.85	24
M 4	0.75	3.25	30	3.50	28	4.20	19	4.40	17
	0.70	3.30	30	3.50	28				
M 4.5	0.75	3.75	25	4.00	22	4.75	13	5.00	9
M 5	1.00	4.00	21	4.40	11/64	5.25	5	5.50	7/32
	0.90	4.10	20	4.40	17				
	0.80	4.20	19	4.50	16				
M 5.5	0.90	4.60	14	4.90	10	5.80	1	6.10	B
M 6	1.00	5.00	8	5.40	4	6.30	E	6.60	G
	0.75	5.25	4	5.50	7/32				
M 7	1.00	6.00	B	6.40	E	7.40	L	7.70	N
	0.75	6.25	D	6.50	F				
M 8	1.25	6.80	H	7.20	J	8.40	Q	8.80	S
	1.00	7.00	J	7.40	L				
M 9	1.25	7.80	N	8.20	P	9.50	3/8	9.90	25/64
	1.00	8.00	O	8.40	21/64				
M 10	1.50	8.50	R	9.00	T	10.50	Z	11.00	7/16
	1.25	8.80	11/32	9.20	23/64				
	1.00	9.00	T	9.40	U				
M 11	1.50	9.50	3/8	10.00	X	11.60	29/64	12.10	15/32
M 12	1.75	10.30	13/32	10.90	27/64	12.60	1/2	13.20	33/64
	1.50	10.50	Z	11.00	7/16				
	1.25	10.80	27/64	11.20	7/16				
M 14	2.00	12.10	15/32	12.70	1/2	14.75	37/64	15.50	39/64
	1.50	12.50	1/2	13.00	33/64				
	1.25	12.80	1/2	13.20	33/64				
M 15	1.50	13.50	17/32	14.00	35/64	15.75	5/8	16.50	21/32
M 16	2.00	14.00	35/64	14.75	37/64	16.75	21/32	17.50	11/16
	1.50	14.50	37/64	15.00	19/32				
M 17	1.50	15.50	39/64	16.00	5/8	18.00	45/64	18.50	47/64
M 18	2.50	15.50	39/64	16.50	41/64	19.00	3/4	20.00	25/32
	2.00	16.00	5/8	16.75	21/32				
	1.50	16.50	21/32	17.00	43/64				
M 19	2.50	16.50	21/32	17.50	11/16	20.00	25/32	21.00	53/64
M 20	2.50	17.50	11/16	18.50	23/32	21.00	53/64	22.00	55/64
	2.00	18.00	45/64	18.50	47/64				
	1.50	18.50	47/64	19.00	3/4				