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# The ULTIMATE COMPILATION of REFERENCES for:

# THREADING

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# SILVER-SMITHING

RUPERT FINEGOLD
WILLIAM SEITZ

# 31

## Taps and Dies

At times the silversmith will want to use screw-on knobs or handles, or to make an object that can be taken apart for cleaning or for ease of transportation, as in the case of a chalice. To do this, threads will have to be cut in the silver. The taps cut the internal (female) threads, and the dies cut the external (male) threads. This chapter will detail the equipment needed and the procedures involved in cutting threads.

As a silversmith, you will use only a few taps and dies, since most of the time you will not be working with wire smaller than a 12 B & S round wire or larger than ¼″/.250″ [6.4mm]. Three different sizes should cover most of your needs when making finials, knobs, and objects to be assembled and disassembled.

In the table at the top of the following page are the three most common wires and the appropriate tap, die, and drill for each.

### EQUIPMENT

#### TWIST DRILLS

The holes to be tapped are cut with twist drills, which have two flutes, or grooves, spiraling around the body of the drill. Use only straight-shank drills of "high-speed steel," indicated by the mark HS or HSS. Although expensive, they are the only type suitable for high speed drilling.

Twist drills are sized in three different ways (see Table 31-3):

1. *Wire gauge number drills,* which run from 1 (the largest) to 80 (the smallest), corresponding to wire gauge sizes. All these drills are smaller than ¼″ [6.4mm] and are used when exact sizing is required.

2. *Letter drills,* which run from A (the

**TABLE 31-1. CORRECT DIE, TAP AND DRILL FOR WIRE SIZES**

| Wire | Die (NC) | Tap (NC) | Drill Size |
|---|---|---|---|
| .250, or $\frac{1}{4}$" sterling | $\frac{1}{4}$–20 | $\frac{1}{4}$–20 | No. 7 ($\frac{13}{64}$") |
| .204, or 4-gauge sterling | 12–24 | 12–24 | No. 16 ($\frac{3}{16}$") |
| .162, or 6 gauge sterling | 8–32 | 8–32 | No. 29 ($\frac{9}{64}$") |

smallest) to Z (the largest), and start where the number drills end at slightly larger than $\frac{1}{5}$". They are used for exact sizing in the larger sizes.

3. *Fractional size drills,* which range in diameter from $\frac{1}{64}$" [.396mm] to over 4" [10.2cm]. The sizes increase by $\frac{1}{64}$" [.396mm] in the smaller sizes and by $\frac{1}{32}$" [.793mm] and $\frac{1}{16}$" [1.6mm] as the sizes increase.

TAPS AND DIES

These can be purchased as a set or individually as your work requires them (Fig. 31-1*a,e*). Get the NC Series, which stands for National Coarse; this series is perfect for silver, since the threads are not too fine. The *tap wrench* is needed to hold the tap; the *diestock* is the holder for the die (see Fig. 31-1*c,f*).

## GENERAL PROCEDURE

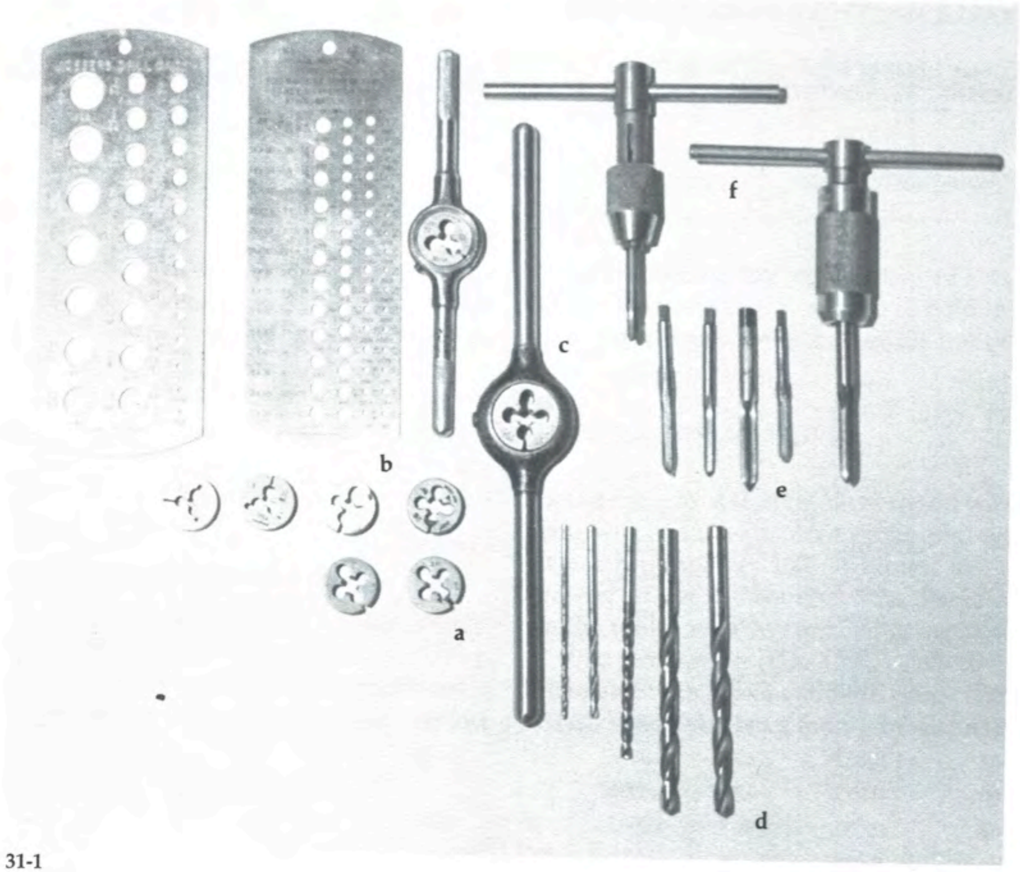
Select the size of sterling silver round wire you will work with. As an example, we use a round wire .162" [4.12mm] in diameter. If you do not know the diameter of the round wire you are using, measure with a micrometer (Fig. 31-2), or check its diameter with a drill and wire gauge (Fig. 31-3). When you have found the diameter

**TABLE 31-2. TAP DRILL CHART**

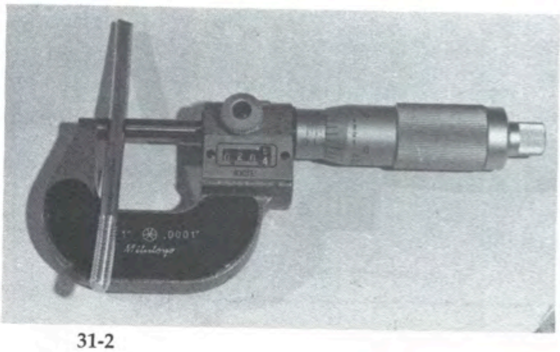
| To Tap for This Size Screw | Drill This Size Hole (Best Drill Size) | Nearest Fractional Size |
|---|---|---|
| 1–64 NC | 53 | $\frac{1}{16}$ |
| 2–56 NC | 50 | $\frac{5}{64}$ |
| 3–48 NC | 47 | $\frac{5}{64}$ |
| 4–40 NC | 43 | $\frac{3}{32}$ |
| 5–40 NC | 38 | $\frac{7}{64}$ |
| 6–32 NC | 35 | $\frac{7}{64}$ |
| 8–32 NC | 29 | $\frac{9}{64}$ |
| 10–24 NC | 25 | $\frac{5}{32}$ |
| 12–24 NC | 16 | $\frac{3}{16}$ |
| $\frac{1}{4}$–20 NC | 7 | $\frac{13}{64}$ |
| $\frac{5}{16}$–18 NC | F | $\frac{17}{64}$ |

## TABLE 31-3. TWIST DRILL SIZES

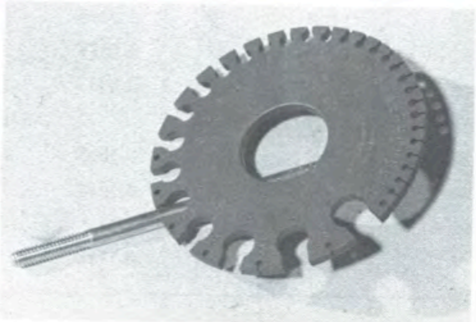
| Diameter | Decimal equivalent | Diameter | Decimal equivalent | Diameter | Decimal equivalent | Diameter | Decimal equivalent | Diameter | Decimal equivalent |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 0.0135 | $\frac{3}{64}$ | 0.0469 | 33 | 0.113 | 12 | 0.189 | J | 0.277 |
| 79 | 0.0145 | 55 | 0.052 | | | 11 | 0.191 | $\frac{9}{32}$ | 0.2813 |
| $\frac{1}{64}$ | 0.0156 | 54 | 0.055 | 32 | 0.116 | 10 | 0.1935 | K | 0.281 |
| 78 | 0.016 | | | 31 | 0.12 | 9 | 0.196 | L | 0.290 |
| 77 | 0.018 | 53 | 0.0595 | $\frac{1}{8}$ | 0.125 | 8 | 0.199 | | |
| | | $\frac{1}{16}$ | 0.0625 | 30 | 0.1285 | | | M | 0.295 |
| 76 | 0.02 | 52 | 0.0635 | 29 | 0.136 | 7 | 0.201 | $\frac{19}{64}$ | 0.2969 |
| 75 | 0.021 | 51 | 0.067 | | | $\frac{13}{64}$ | 0.203 | N | 0.302 |
| 74 | 0.0225 | 50 | 0.07 | $\frac{9}{64}$ | 0.1406 | 6 | 0.204 | $\frac{5}{16}$ | 0.3125 |
| 73 | 0.024 | | | 28 | 0.1405 | 5 | 0.2055 | O | 0.316 |
| 72 | 0.025 | 49 | 0.073 | 27 | 0.144 | 4 | 0.209 | | |
| | | 48 | 0.076 | 26 | 0.147 | | | P | 0.323 |
| 71 | 0.026 | $\frac{5}{64}$ | 0.0781 | 25 | 0.1495 | 3 | 0.213 | $\frac{21}{64}$ | 0.328 |
| 70 | 0.028 | 47 | 0.0785 | | | $\frac{7}{32}$ | 0.21875 | Q | 0.332 |
| 69 | 0.0292 | 46 | 0.081 | 24 | 0.152 | 2 | 0.221 | R | 0.339 |
| 68 | 0.031 | | | 23 | 0.154 | 1 | 0.228 | $\frac{11}{32}$ | 0.34375 |
| $\frac{1}{32}$ | 0.0313 | 45 | 0.082 | $\frac{5}{32}$ | 0.15625 | A | 0.234 | | |
| | | 44 | 0.086 | 22 | 0.157 | | | S | 0.348 |
| 67 | 0.032 | 43 | 0.089 | 21 | 0.159 | $\frac{15}{64}$ | 0.2344 | T | 0.358 |
| 66 | 0.033 | 42 | 0.0935 | | | B | 0.238 | $\frac{23}{64}$ | 0.359 |
| 65 | 0.035 | $\frac{3}{32}$ | 0.0938 | 20 | 0.161 | C | 0.242 | U | 0.368 |
| 64 | 0.036 | | | 19 | 0.166 | D | 0.246 | $\frac{3}{8}$ | 0.375 |
| 63 | 0.037 | 41 | 0.096 | 18 | 0.1695 | $\frac{1}{4}$ | 0.250 | | |
| | | 40 | 0.098 | $\frac{11}{64}$ | 0.1719 | | | V | 0.377 |
| 62 | 0.038 | 39 | 0.0995 | 17 | 0.173 | E | 0.250 | W | 0.386 |
| 61 | 0.039 | 38 | 0.1015 | | | F | 0.257 | $\frac{25}{64}$ | 0.3906 |
| 60 | 0.04 | 37 | 0.104 | 16 | 0.177 | G | 0.261 | X | 0.397 |
| 59 | 0.041 | | | 15 | 0.18 | $\frac{17}{64}$ | 0.2656 | Y | 0.404 |
| 58 | 0.042 | 36 | 0.1065 | 14 | 0.182 | H | 0.266 | | |
| | | $\frac{7}{64}$ | 0.1094 | 13 | 0.185 | | | $\frac{13}{32}$ | 0.4063 |
| 57 | 0.043 | 35 | 0.11 | $\frac{3}{16}$ | 0.1875 | I | 0.272 | Z | 0.413 |
| 56 | 0.0465 | 34 | 0.111 | | | | | | |




31-1



31-2



31-3

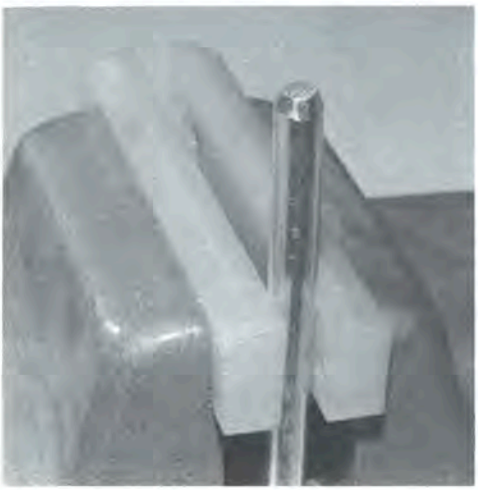
31-1. (a) Dies; (b) drill gauges; (c) diestock; (d) drill bits; (e) taps; (f) tap wrench.

31-2. Using a micrometer to measure a silver rod. It measures .204 inch, or 4 gauge.

31-3. Measuring the silver rod with the B&S wire gauge. It also measures .204 inch; on the other side of the gauge, it reads 4 gauge.

of the wire, use Table 31-2 to find the drill size. In this example, the closest is a No. 29. The proper size tap is 8–32NC, which stand for No. 8 machine screw with 32 threads to the inch, National Coarse series. The other designation (8–36 NF) is National Fine. We prefer the National Coarse series for silver work.

Now, cut the external threads with the die, as explained below. Then cut the internal threads with the tap after drilling a hole for the tap, as explained below. The hole need not be precise. A variance of a few thousandths of an inch one way



31-4. The end of the silver rod is beveled with a file to allow the die to fit easily over the rod.

or the other doesn't matter, particularly when cutting a soft material like silver.

CUTTING EXTERNAL THREADS

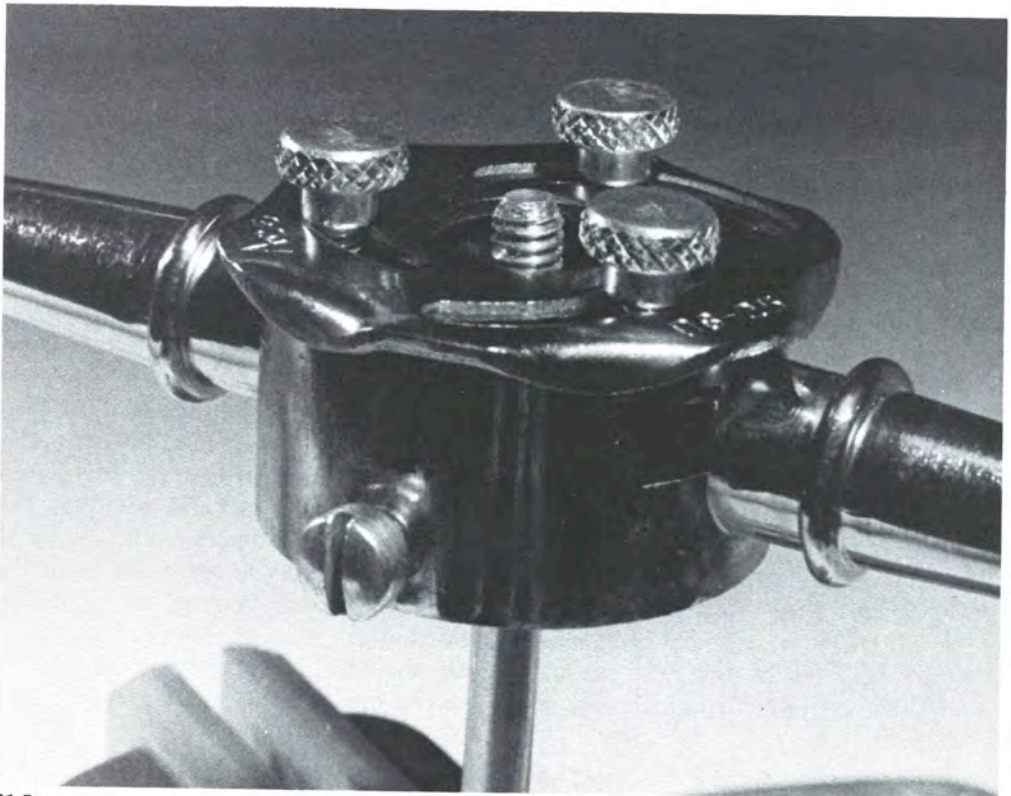
To begin cutting the external threads, clamp the wire firmly in the vise, straight up, and bevel its end with a file (Fig. 31-4). Then, with the die in the diestock or die holder, place the die on the wire. Make sure that the die is facing the proper way. Look at it and note that on one side sharp threads extend to the end; on the other side they seem slightly worn away. The side with the worn-looking threads is the side that first meets the silver. Make sure that the diestock is not slanted; if it is, the threads will be cut crooked. It is easier if you have a helper to see if it is level.

Use a lightweight oil to aid in cutting the threads. After you have turned the die one revolution, reverse it a quarter turn to break the chip (a curve of metal) that has formed. Then continue cutting, breaking the chip afte each revolution. This is easy to do once you have it started (Figs. 31-5 and 31-6).

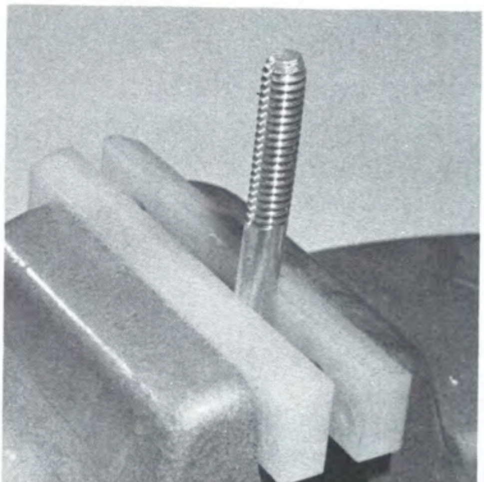
CUTTING INTERNAL THREADS

Drill a hole in the workpiece with the tap drill suited to the tap you have selected. If you use a drill press, this is easy. If you use a hand drill, make sure to hold it absolutely vertical.

After the hole is drilled, insert the tap and gently start to press and twist it. Ensure that the tap is vertical by using a small square (Fig. 31-7). After the tap is started, make a half-turn and then back up one-quarter turn to break the chip. Keep doing this until the tap is through the hole



31-5



31-6

31-5. After the die has been fitted into the diestock, which holds it for cutting, the threads can be cut. Remember to use a lightweight cutting oil, and back up one-quarter turn after each revolution.

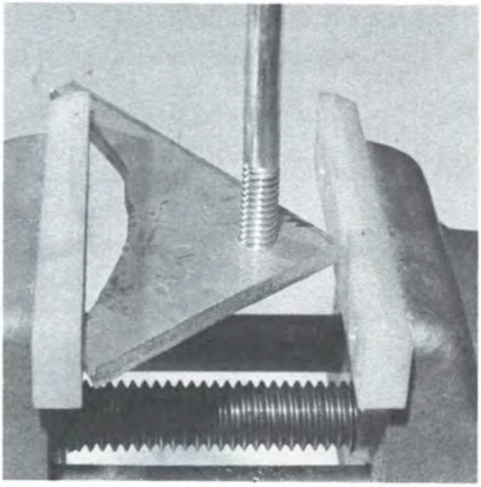
31-6. The finished threads.

31-7. The hole has been drilled in the silver and the tap started. The small square is used to keep the tap vertical. Remember to back up one-quarter turn after each revolution.

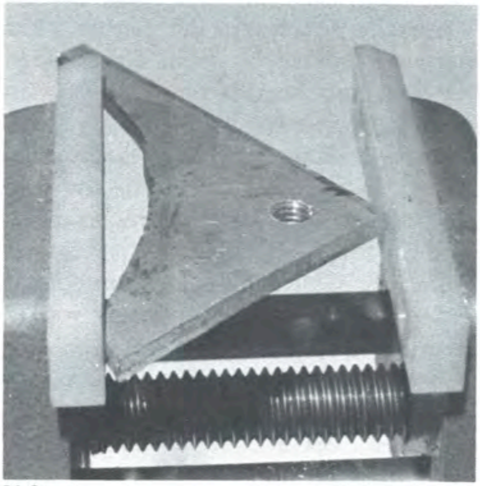
31-8. The finished tap.

31-9. The tap and die should make a perfect fit.

31-7



31-9

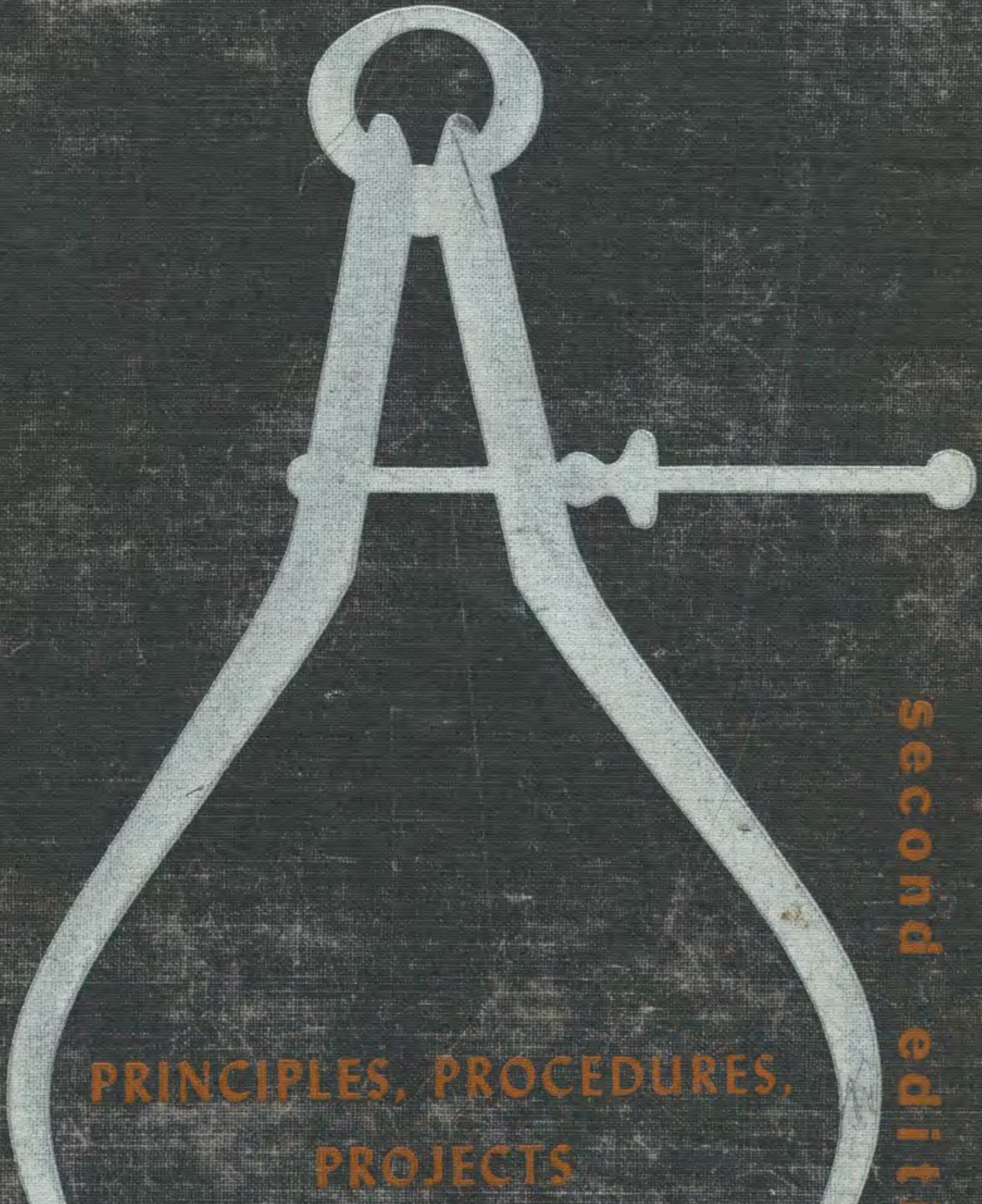


31-8

to the point where the threads on the tap are fully cut (Figs. 31-8 and 31-9). Use a lightweight oil for lubrication.

The hole that you have just tapped is the type most frequently encountered in silversmithing. Called a *fully tapped hole,* it goes all the way through the material. The second type that you might have a need for is called a *blind hole;* it goes only partway through. You will need three taps instead of one to tap a blind hole. Start with a *taper tap* and, after the threads have started to cut, use a *plug tap* almost to the end of the hole. Then, with a *bottoming tap,* complete the threading of the blind hole.

# GENERAL METAL



PRINCIPLES, PROCEDURES, PROJECTS

FRASER · BEDELL

second edition

5

# Taps and Dies

*This chapter covers the following subjects:*



## Kinds of Threads

The four most common types of screw threads (see Fig. 5–1) are the V-thread, the National Form thread, the Square thread, and the Acme thread. Of the four types, the National Form thread is the most generally used. It is made with either a fine or a coarse thread. Coarse threads are used for ordinary fastenings, whereas fine threads are used in finely machined parts, such as automobile parts.

Threads may be either right-handed or left-handed. A tap (see Fig. 5–2) is used to cut the threads in a drilled hole. A die (see Fig. 5–3 )is used to cut threads on a bolt. The number of complete spirals per inch is the number of threads per inch (see Fig. 5–4).

The size of a tap or die is always stamped on it. For example, the notation ⅜-16 NC stamped on either a tap or a die means it will cut a thread ⅜ inch in diameter, with 16 threads to the inch, and the threads will be National Coarse (or, if NF, National Fine).

**Drill Sizes for Cutting Threads with a Tap.** A tap (see Fig. 5–2) is used to cut threads on the inside of a hole. Therefore, a hole must be made before threads can be cut with a tap. Since taps are made to standard sizes, the hole into which threads are to be cut must be drilled according to the size of the tap to be used. Because most holes in metal are drilled, it is only logical that a drill of the correct size must be used for each different size of tap. These different drill sizes can be secured from any machinery handbook. To help you, some of the tap drill sizes are given in Table 2.

## Hand Taps

There are three different styles of taps (see Fig. 5–2) in general use: the taper tap, the plug tap, and the bottoming tap. As their names imply, they are intended for different purposes. The

TABLE 2

TAP DRILL SIZES FOR NATIONAL COARSE AND NATIONAL FINE THREADS

| *Size of Tap* | *Threads per Inch* NC | NF | *Tap Drill Size* NC | NF |
|---|---|---|---|---|
| 6 | 32 | 40 | #36 | #33 |
| 8 | 32 | 36 | #29 | #29 |
| 10 | 24 | 32 | #25 | #21 |
| 12 | 24 | 28 | #16 | #14 |
| 1/4 | 20 | 28 | 13/64 #7 | #3 |
| 5/16 | 18 | 24 | 1/4 (F) | I |
| 3/8 | 16 | 24 | 5/16 | Q |
| 7/16 | 14 | 20 | 23/64 | 25/64 |
| 1/2 | 13 | 20 | 27/64 | 29/64 |

taper tap is the one most generally used in the general metal shop.

## Tap Wrench

A tap wrench holds taps for turning when you are cutting internal threads. There are two types of tap wrenches (see Fig. 5–5): the adjustable tap wrench for large taps and the T-handle for small taps and for use in restricted areas.

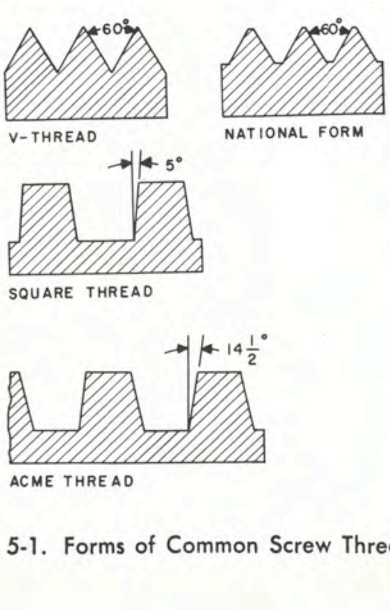
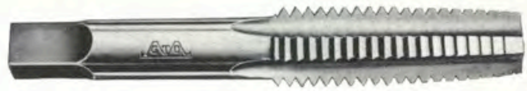
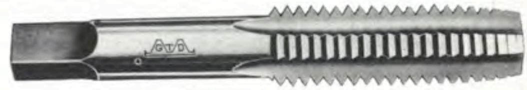



Fig. 5-1. Forms of Common Screw Threads.



(a) Taper tap, for any drilled hole.



(b) Plug tap, for blind hole.

(c) Bottoming tap, for finishing threads to bottom of blind hole.

Fig. 5-2. Hand Taps. (*Courtesy Greenfield Tap & Die Corp.*)

**Using a Tap to Cut Threads on the Inside of a Hole.** To make sure that you are using a drill of correct size for the tap, consult Table 2. After selecting the drill, drill a hole in the metal (see Fig. 13–15, p. 153). Insert the tap in the hole. Then turn the tap slowly two or three turns while bearing down on the handles of the tap wrench (see Fig. 5–6a). After one or two threads have been cut, check to see if the tap is entering the hole straight up and down. Fig. 5–6b shows one method of checking for squareness. The tap should be tested for squareness on at least two sides. If it has not been started square, back the tap out of the hole a few turns and correct the position by applying a sidewise pressure on the tap wrench while again turning it into the hole. Again, check to see if the tap has been started square with the surface of the metal. After it has been started square, the tap must not be forced too rapidly. It is a good plan to turn the tap forward about a quarter turn, then back it off a little and repeat the forward turn. A lubricant, such as cutting oil or a mixture of white lead and oil, should be used liberally when cutting threads. Continue the forward and backward turns until the threading has been completed.

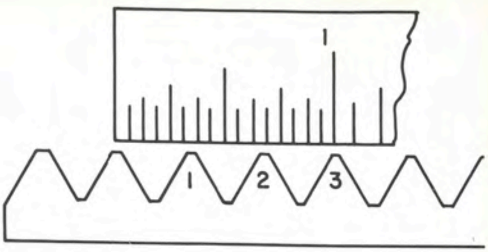
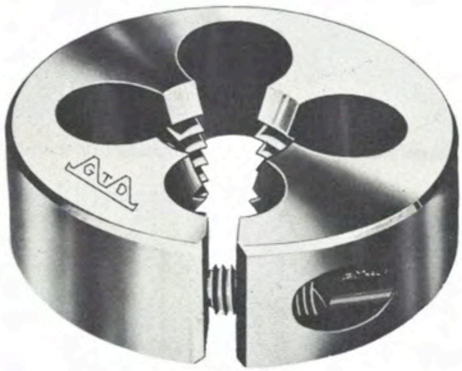
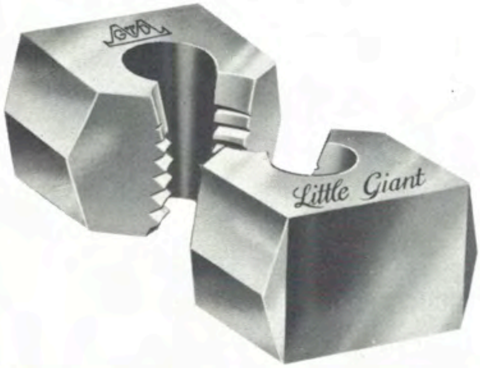



Fig. 5-4. From the top of the thread touching the end of the rule to the top of the next thread would be one thread. Counting for the rest of an inch would give the number of threads to the inch. In the illustration it would be three threads to the inch.



(a) Round adjustable die.

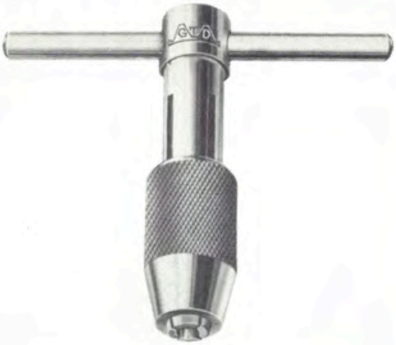



(b) Adjustable die.

Fig. 5-3. Dies. (*Courtesy Greenfield Tap & Die Corp.*)

## Dies

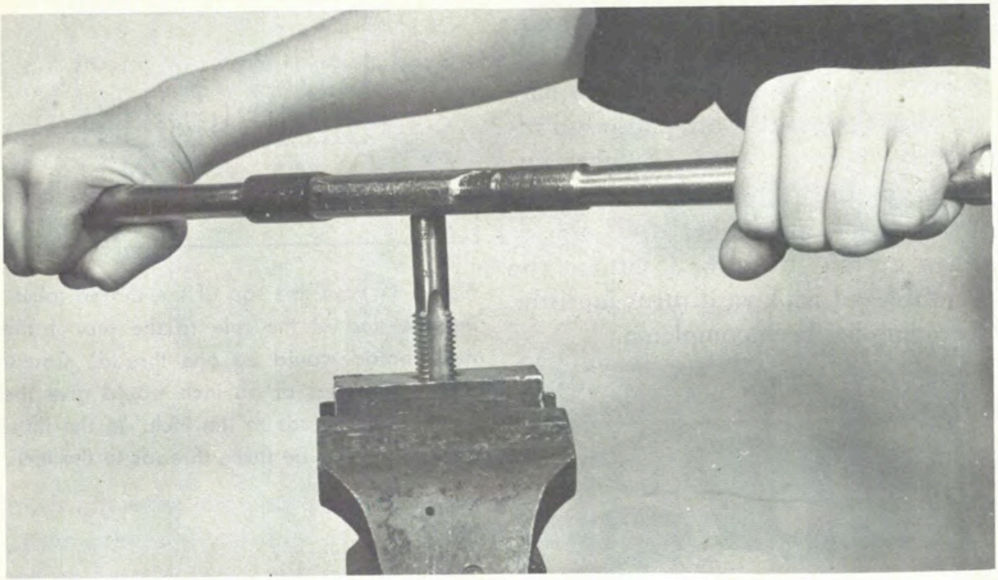
A die (see Fig. 5–3) is used to cut threads on the outside of a bolt or a rod. There are two different styles of dies in general use, the round adjustable die and the two-piece die.



(a) T-handle tap wrench.

(b) Straight handle tap wrench.

Fig. 5-5. Tap Wrenches. (*Courtesy Greenfield Tap & Die Corp.*)



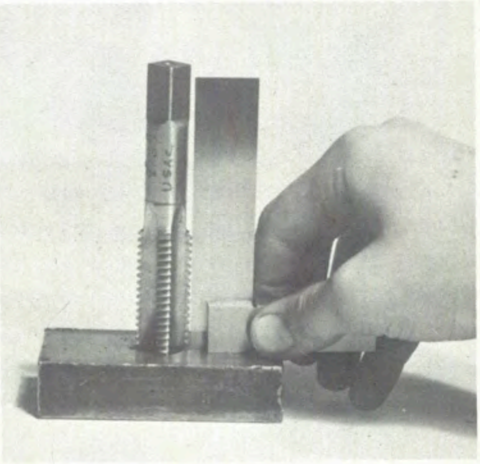


Fig. 5-6. A tap is hard and brittle; for this reason, it is liable to break easily. You should use great care when you are turning the wrench, so as not to break the tap. *Above:* starting a tap in a drilled hole. *Right:* checking a tap for squareness after it has been started.

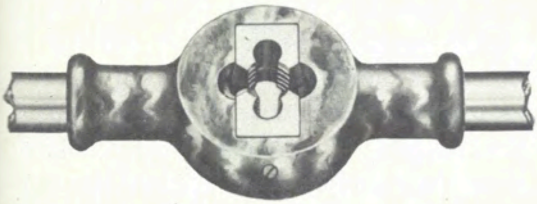
**Adjustable Die.** The round adjustable die (see Fig. 5–3) is circular in shape, with a split from the edge to the opening in its center. By turning the adjusting screw you can make the die cut a slightly larger- or smaller-diameter thread. Thus it is possible to obtain either a tight- or a loose-fitting thread.

**Two-Piece Die.** The two-piece die (see Fig. 5–3) is made in two separate pieces. These pieces must be placed in a die stock designed to hold them. They are then adjusted to cut the thread desired by turning the adjusting screws of the die stock.

## Die Stock

A die stock is a kind of wrench for holding the die while it is being turned to cut threads on a bolt or rod. There are two types of die stocks (see Fig. 5–7). The one shown in Fig. 5–7a holds the round adjustable die, and the one shown in Fig. 5–7b holds the two-piece die.

(a) Die stock for round adjustable die.



(b) Die stock for adjustable die.

Fig. 5-7. Die Stocks. *(Courtesy Greenfield Tap & Die Corp.)*

**Using a Die To Cut Threads on a Rod or Bolt.** To cut threads on a rod or bolt, a die (see Fig. 5–8) must first be selected. This die must be the same size as the outside diameter of the metal. It is sometimes difficult to start the cut. To overcome this problem, grind or file a slight taper or chamfer (see Fig. 5–9) on the end of the rod. Now, place the die on the end of the rod and slowly turn the die stock two or three turns while bearing down on the handles. After cutting about two turns, sight from two directions along the handles of the die stock to see if it

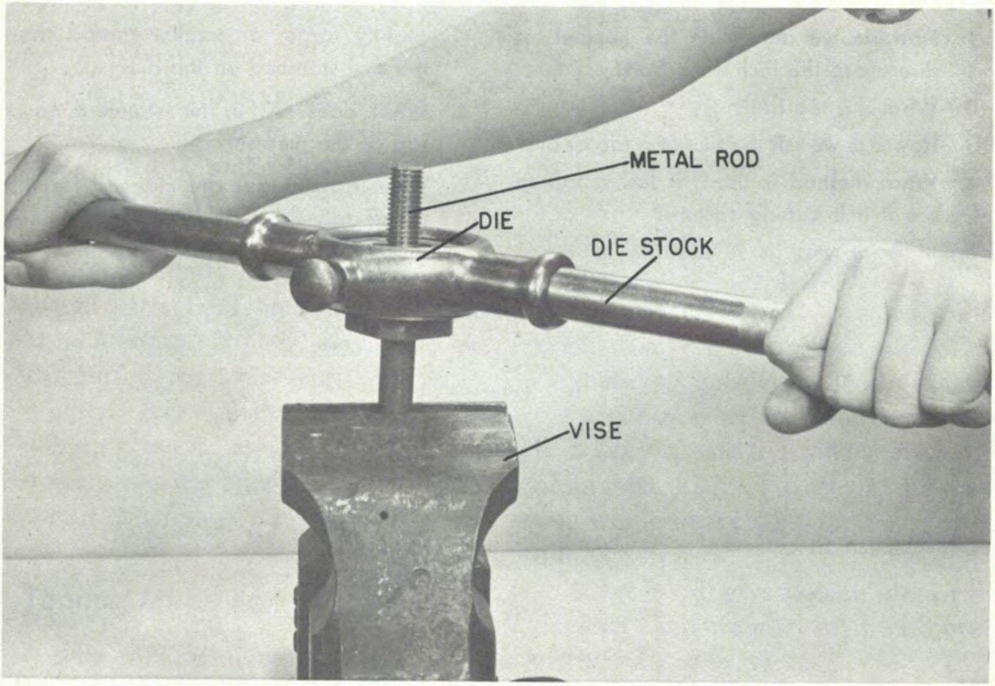



Fig. 5-8. Cutting Threads With a Die. After a thread has been cut, it should be tested by being screwed into the internal thread with which it is to be used. If it fits too tightly, adjust the die to cut a smaller thread. It is always best to cut a thread that is too large. Then adjust the die for a light finishing cut of the thread for a perfect fit.

Fig. 5-9. Chamfered End of a Rod.

is cutting square with the rod or bolt. If it has not been started square, back the die up a few turns and apply a sidewise pressure to correct the position; then again start turning the die onto the rod. Again check to see if it has been started square. Once it is cutting square, it should be turned from one-half to three-quarters of a turn and then backed up one-half turn. Continue the forward and backward turning until the thread is cut. Cutting oil or a mixture of white lead and oil should be used with a die, just as with a tap.

## Questions

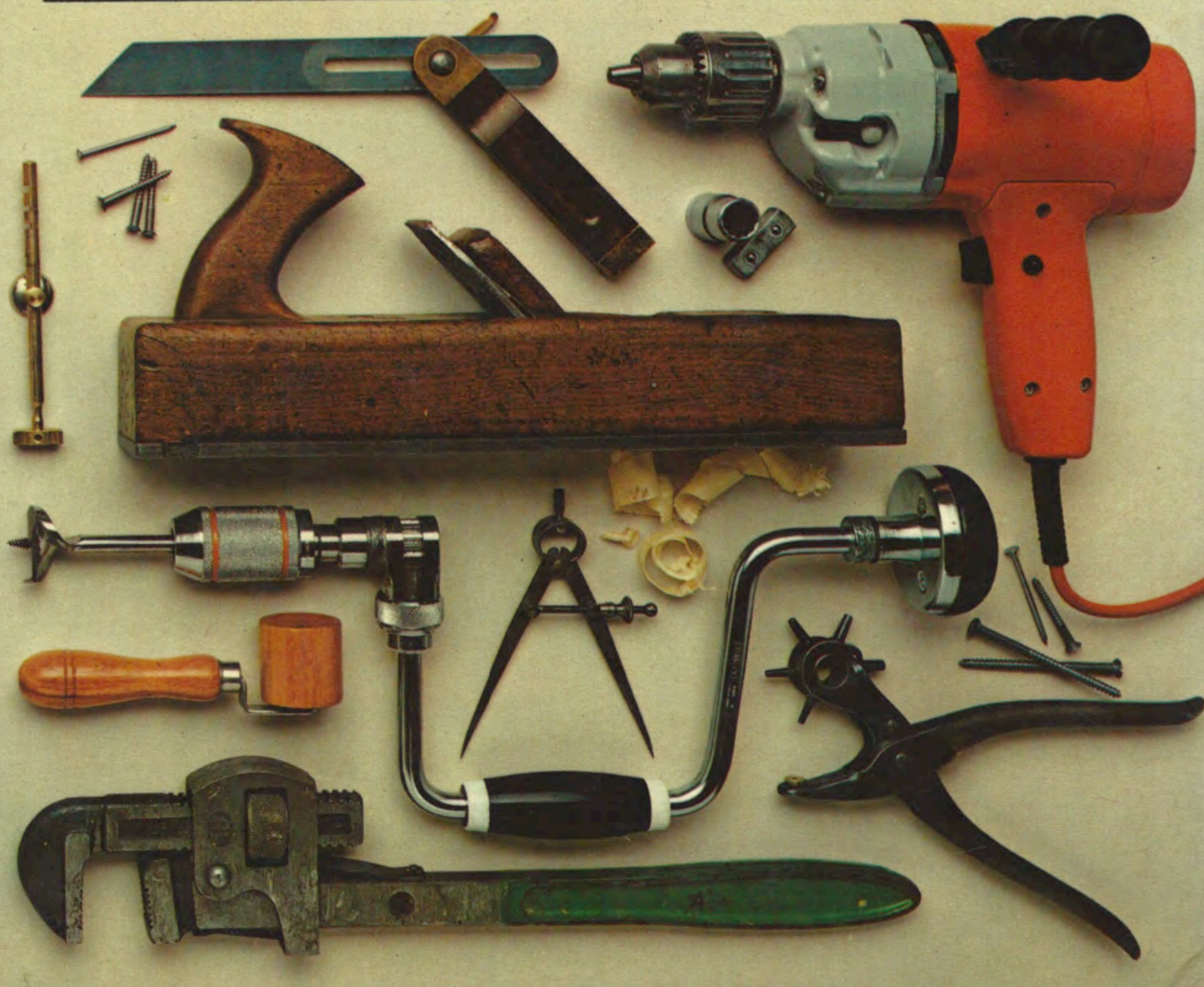
1. How do we determine the number of threads to the inch on a bolt?
2. What is a tap drill?
3. How can we tell the size of a tap or die?
4. What method is used to test a tap to see if it is cutting square?
5. In what way is it possible to cut a slightly larger or smaller thread than the size stamped on the die?
6. What does NC or NF stamped on a tap or die mean?
7. What advantages are claimed for the round adjustable die over the two-piece die?

Albert Jackson & David Day

# Tools

## AND HOW TO USE THEM

An illustrated encyclopedia of hand and power tools from the ordinary to the odd—their history, what they are used for, how to operate and maintain them



# Taps and Dies

Taps and dies are tools used to cut threads for nuts and bolts. One of the earliest forms of tap was illustrated by Leonardo da Vinci toward the end of the fifteenth century. It was a set of three short square sectioned bars with the thread cut deeper on each face, mounted like a star so that each tap could be turned using the other two as handles. These were used for tapping the screw box, an early form of die, which cut the corresponding screw thread on a turned cylinder, usually made of hardwood in those days.

**SCREW THREAD TYPES**
When screw threads were cut with smith-made taps and dies there was no standardization, as each workshop used its own pattern. Even now there are many different screw thread types, far more than necessary, some differing from each other by only small amounts. Those most likely to be encountered are as follows:

**B.A. (British Association)**
Used on the small screws extensively used in electrical equipment, available in 16 sizes, Nos. 0–15 (0.236 to 0.031in.)

**B.S.W. (British Standard Whitworth)**
Made from $\frac{1}{4}$in. diameter upward, rising in $\frac{1}{16}$in. steps. Now obsolete, this was the first standard thread in Britain, but was found to be too coarse for some applications. The steepness of the thread gives too little clamping force in the presence of vibration. It is now used for soft or weak materials such as aluminum or cast iron or for cheaply made nuts and bolts where accuracy is not important.

**B.S.F. (British Standard Fine)**
This was introduced to overcome the lack of clamping force of B.S.W. and is made in the same sizes.

**UNF Unified Fine, UNC (Unified Coarse)**
the American equivalent of Whitworth and B.S.F. Made from $\frac{1}{4}$in., rising in $\frac{1}{16}$in. steps.

**Metric Coarse**
This thread is made in diameters from 1 to 300mm and is recommended for all general work.

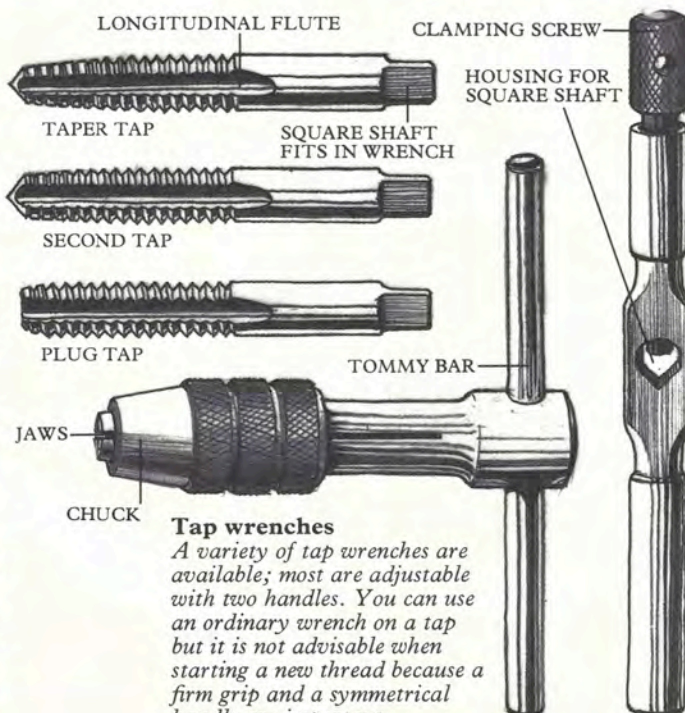
**Metric Fine**
There are various fine threads for special purposes such as in machinery where vibration would loosen the fixing.

## Taps

SIZE: See above
MATERIAL: Steel
ACCESSORIES: Tap wrench
USE: To cut internal screw threads as for a nut

A tap is a length of high speed steel cut with the thread form of a bolt, but having longitudinal flutes which form cutting edges and allow clearance for the swarf (metal shavings). In place of a bolt's hexagonal head the tap has a small square shaft to fit a tap wrench.

Taps usually come in sets of three. The first, and forming tap, is the "taper", which is tapered for at least half its length, sometimes down to the minor diameter at the tip. This provides an easy start to the threading operation. The "second", and "bottoming" or "plug" taps are progressively less tapered. All three cut the full thread, so that in thin plate the taper tap may be all that is necessary.



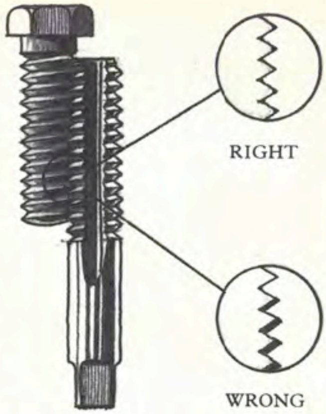

**Tap wrenches**
*A variety of tap wrenches are available; most are adjustable with two handles. You can use an ordinary wrench on a tap but it is not advisable when starting a new thread because a firm grip and a symmetrical handle are important.*

**Matching a thread to a bolt**
If a bolt hole has been stripped of its thread, it is necessary to match the tap to a larger bolt. If you know the thread type and size, look for the appropriately marked tap. If you do not, measure the bolt with calipers to ascertain the right diameter. Alternatively, use a screw pitch gauge. Compare the thread of the bolt with that of the tap by fitting them together: they should marry exactly. If you are in any doubt, take the bolt to be matched by a tool supplier.

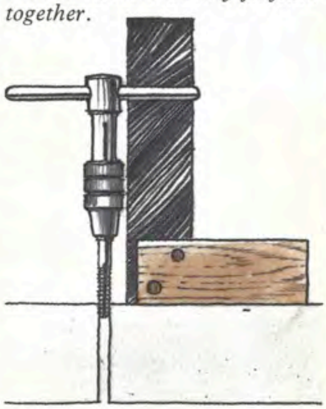
**Starting a threaded hole**
To make a thread mark the position of the hole and center punch it. If the work is important or is likely to be subjected to high stress, use the correct tapping drill for the tap and the material being worked. Alternatively, select a drill slightly larger than the minor diameter of the thread. If the drill is the same size or smaller than this the tapping will be stiff and the tap may break.

Fit the taper tap into the wrench and position it in the hole. Make sure you align the tap with the hole as it will be impossible to correct misalignment once cutting has begun.

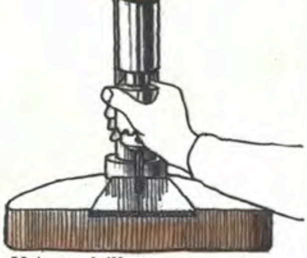
For accuracy, use a lathe or drill press to start the thread Do not use the power unless you have an automatic tapping device but turn the machine by hand to avoid breaking the tap. In each case provide pressure into the work while turning. Once the thread is started it can be continued by hand.



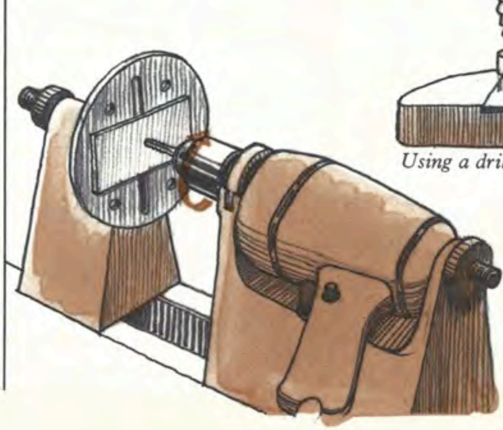

**Marrying thread and bolt**
*Press the thread of the tap to the bolt to see that they fit flush together.*



**Keeping the tap straight**
*Use a try square to check for true in two directions at right angles.*

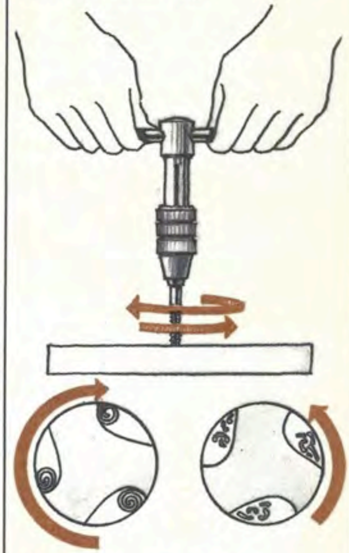


*Using a drill press*



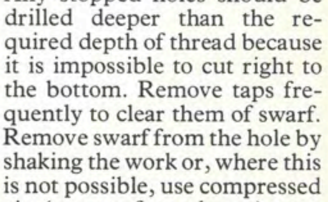
*Using a lathe*

**Completing the thread**
Use tallow or oil lubricants for steel and turpentine for copper or aluminum. Thread brass and cast iron dry.



*Turn the tap back ¼ turn to break the swarf then proceed with a ½ turn back and so on.*

**Threading deep holes**
Cut part of the thread using the three taps in sequence then start again with the taper tap and repeat the process. This will reduce the strain on the taps and lessen the chance of breakage.

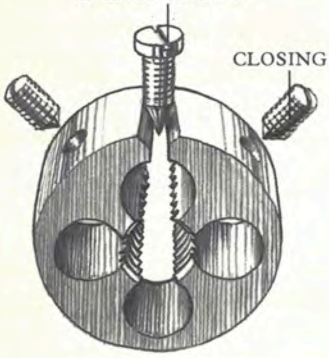


Any stopped holes should be drilled deeper than the required depth of thread because it is impossible to cut right to the bottom. Remove taps frequently to clear them of swarf. Remove swarf from the hole by shaking the work or, where this is not possible, use compressed air (wear safety glasses) or a greased rod. Take care when approaching the bottom of a hole; if you go too far, the tap can easily break.

# Dies

SIZE: See page 266
MATERIAL: Steel
ACCESSORIES: Stock or handle
USE: To cut external screw threads as for a bolt

**ROUND SPLIT DIE**
The most common type of die is the split ring or round split die. This has a central threaded hole with a slight chamfer at one end.

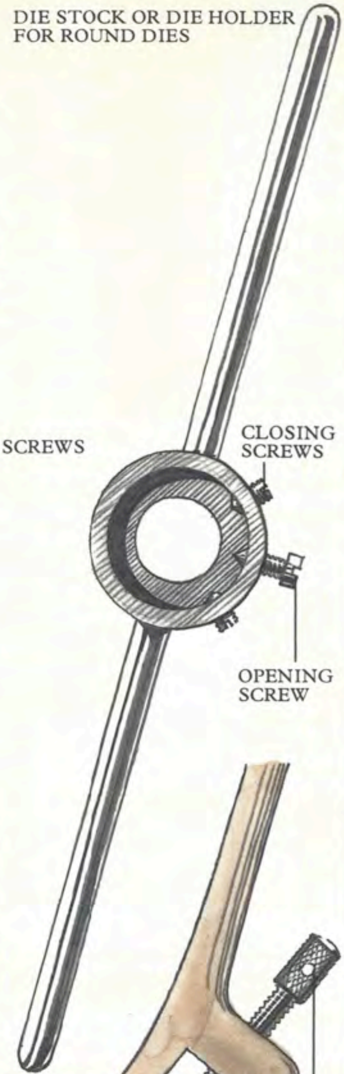


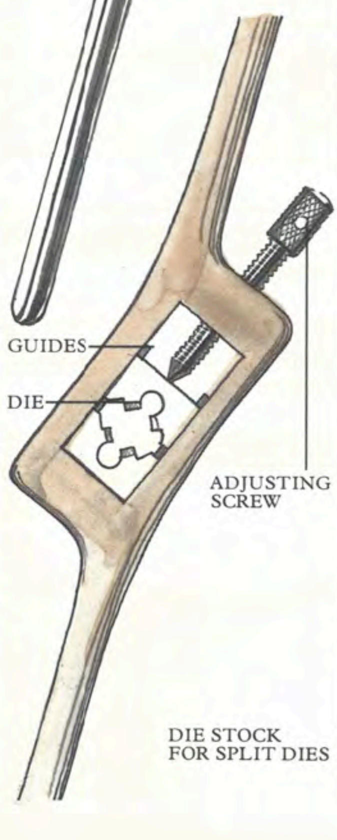

ROUND SPLIT DIE

Three or four holes grouped around the central one form cutting edges. The die is split to allow for adjusting by means of screws in the stock. To open it, the locking screws are backed off and the adjusting screw screwed in; the locking screws are then tightened to secure it. The die can be closed by backing off the adjusting screw until the natural spring of the die closes the gap. To close the die further, tighten the locking screws. This adjustment provides a good fit between nut and bolt and also allows metal to be removed in easy stages.

**SPLIT DIES**
The other common type of die is the split die, which consists of two rectangular jaws assembled in the stock and operated by means of a single adjusting screw. This type of die allows more adjustment than the round split die.

DIE STOCK OR DIE HOLDER FOR ROUND DIES

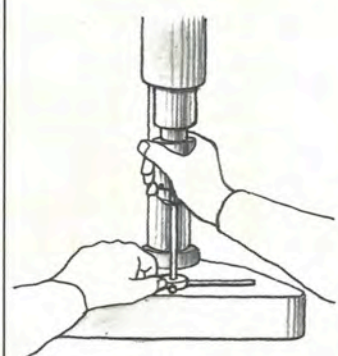



DIE STOCK FOR SPLIT DIES

**Threading a rod**
First cut a 5° to 7° chamfer on the end of the rod for about $1\frac{1}{2}$ diameters. Open the die (and tighten the locking screws in the case of a split ring die) and place it on the end of the rod which must be firmly held. Press down and turn while keeping the die square to the rod. Once the die has begun to bite, no further pressure is required. Proceed a half turn forward and a quarter turn backward to break the swarf and lubricate as for tapping.

**Preparing for another cut**
*Having completed the required length of thread, wind the die back to the beginning and tighten for another cut. Check the fit of the nut after each cut.*

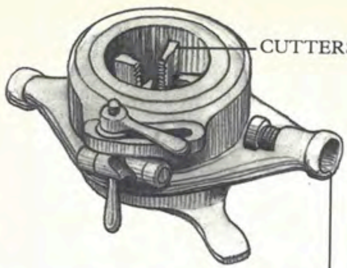


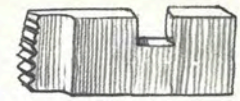
**Using a drill press**
*Rest the die stock on the bed of the machine, chamfer uppermost, and hold firmly. Insert the rod in the chuck which should be hand turned. You can also use a lathe, fitting the work in the chuck and the die stock on a face plate.*

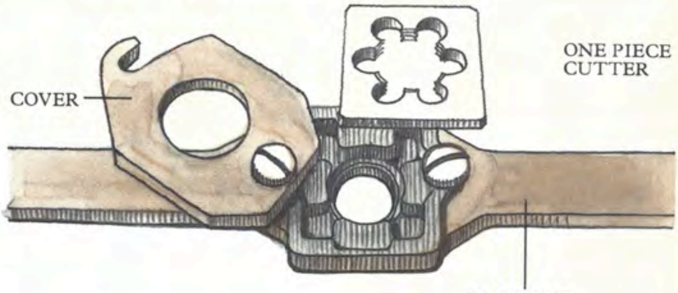
# Pipe Die

SIZE: $\frac{1}{4}$ to $1\frac{1}{4}$in.
MATERIAL: Steel
ACCESSORIES: Diestock, guide bushing
USE: To cut a screw thread on pipework

The pipe die can be a one piece cutter made to fit a particular pipe size, or adjustable if constructed from separate jaws. You need a guide to align the die with the pipe: this can be either part of the stock itself or a separate bushing which fits into it along with the die. The cutting sequence is the same as that for normal thread cutting, with the die being lubricated every 2 to 3 turns. Some diestocks have ratchets so the tool can be used in confined spaces.



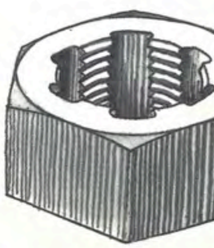




# Die Nut

OTHER NAME: Rethreading die
SIZE: See page 266
MATERIAL: Steel
USE: To recut damaged or rusty machine screw threads

A die nut can be used to clean up an existing thread. It is not adjustable and must be matched to the screw thread. It can be driven with any convenient wrench.



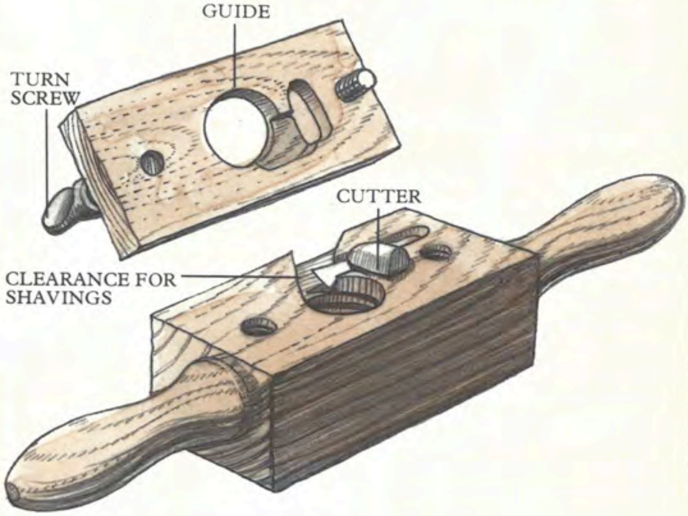
# Screw Box

SIZE: To thread from $\frac{5}{8}$ to 3in. diameter
MATERIAL: *Box:* wood; *Cutter:* metal
USE: To cut threads in wood

The screw box is made in two parts and is held together by screws. The cutter is mounted between the two. The first section of the box is smooth bored to act as a guide when starting the cut. With the wooden dowel held in a vise, the box is engaged on the end and turned clockwise until it begins to cut.

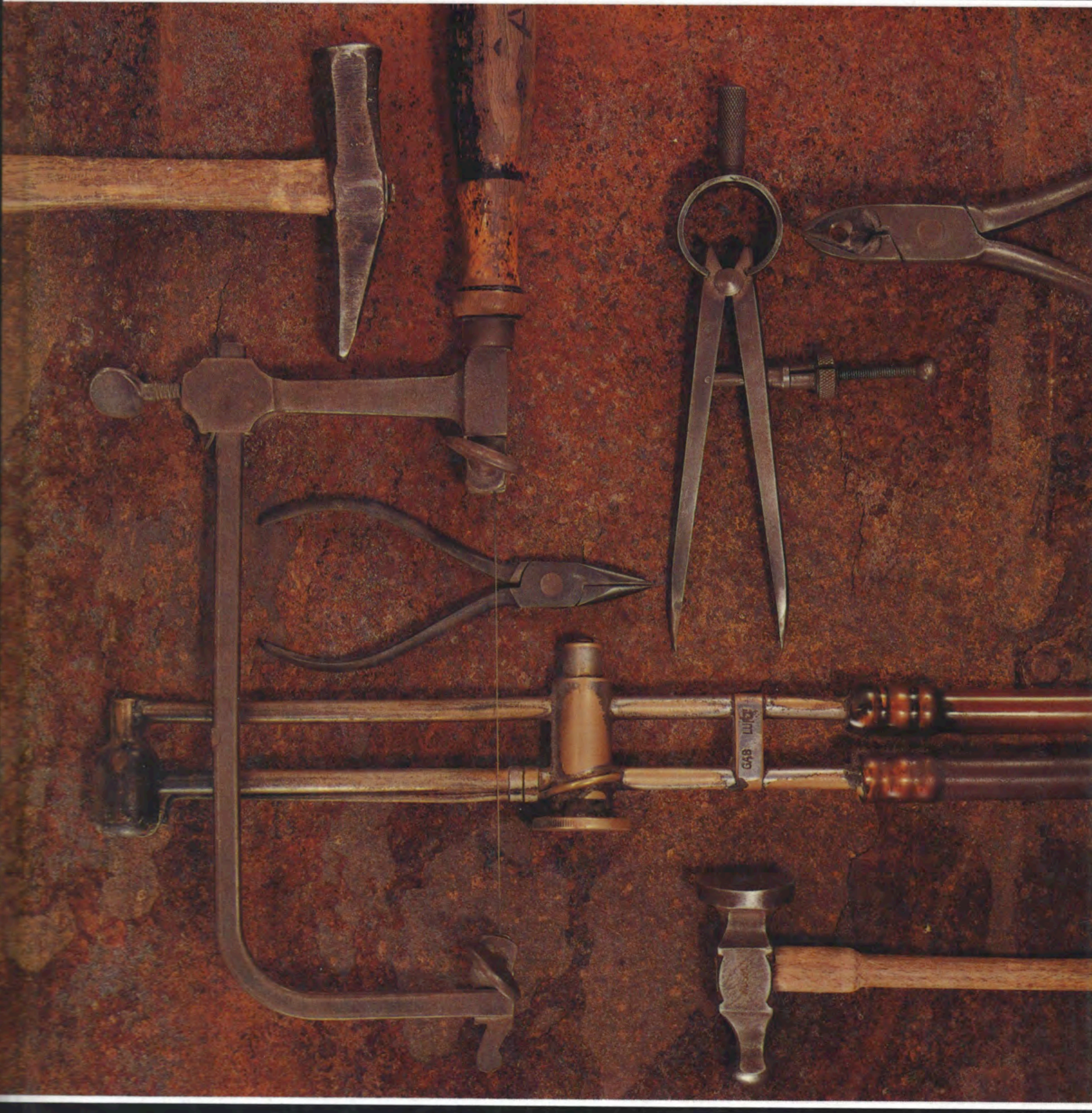
Internal threads are cut with a tap like those used for metal.

While now rare, wooden threads were once extensively used in hand tools such as clamps and rabbet planes. Today, wooden screws are used in marking gauges.




# Practical jewelry making

Loosli / Merz / Schaffner




UBOS / SCRIPTAR

## 20 Screwing, riveting

**Purpose of instruction**

- Making technically correct male and female threads and rivets, with the usual tools

**Purpose of exercises**

Screws and nuts

- cutting male threads to given dimensions (screw)
- drilling and tapping the corresponding holes (nut)
- in thin and thick plates (single or superposed plates)
- in thick-walled hinge tubes
- making convex and countersunk screwheads

Rivets

- preparing rivets of given lengths and thicknesses
- drilling the corresponding holes
- in thin and thick plates
- in single or superposed plates
- mobile or fixed rivets, with or without intermediate spaces
- in hinge tubes (for brooches), conical boring out with the reamer
- making convex and countersunk rivet heads
- correctly forging rivets heads

**Recommendations**

- Rule of thumb for calculating the dimensions of holes that are to be drilled:
  under 3 mm
  desired diameter of female thread multiplied by 0.7
  (e.g. 2-mm thread = bore $0.7 \times 2$ mm = 1.4 mm)
  over 3 mm
  desired diameter of female thread multiplied by 0.8
  (e.g. 4-mm thread = bore $0.8 \times 4$ mm = 3.2 mm)
- first rough out the hole then finish it with the finishing tap
- approach the thread-cutter and the tap at right-angles to the surface of the workpiece
- tap half a turn, then go back a quarter of a turn
- cut threads with oil or soap
- explain how to look after the tools
- draw attention to the delicate nature of the tools

**Training period** about one week

**Actual duration**

**Notes**

Date Signature

# 20 Screwing

## Procedure

Screwing is a method of assembling parts of workpieces by means of screws and nuts or of screws alone. It differs from all other assembling techniques inasmuch as it enables one to separate and reassemble parts at will.
For cutting stable threads in soft precious metals, special cutting tools are available. The pitch of these threads is somewhat steeper than the metric pitch; furthermore, the thread-cutting is graduated: the smaller the diameter, the coarser the thread. These are known as jewelers' threads (with coarse pitch).
Screwing plays a very special part in jewelry making. Even though certain screwing systems are found on the market, the jeweler must be capable of making all his threads, nuts and screws himself. Before special thread-cutting tools came into general use, jewelers used to cut rather coarsely dimensioned threads by hand. Even today, for jewelry made in a rather primitive manner, threads are made without the help of cutting tools: a thin wire, wound in a spiral, is brazed onto a thicker wire or into a hinge as the case may be.

## Tools

### Screw plate

(coarse thread)
Even today, this screw plate is sometimes used in its original form. It can also be used for making taps. On one side, there are about fifteen holes, graduated from 0.7 to 2.0 mm, for starting the thread-cutting operation. The other side has the same number of holes for finishing the work.

### Die stock

(coarse thread)
Each die is fixed into a holder, or stock. By means of an adjusting screw, it can be adapted for graduated thread-cutting operations.

### Screw dies

(metric thread)
As in the case of the die stock, individual dies can be fitted onto a two-armed holder; they are interchangeable and adjustable. For precious metals, the metric thread is suitable only from about 1.0 mm (for hard white gold from about 0.5 mm).

### Taps

For every set of screw-cutting tools, there exists a corresponding set of taps:

1. roughing taps
2. enlarging taps
3. finishing taps

For starting the hole, roughing taps are necessary. Their form is essentially similar: slightly tapered, with three grooves for removing swarf.


**I Screw plate**
1 for roughing
2 for finishing

**II Die stock**
1 adjusting screw

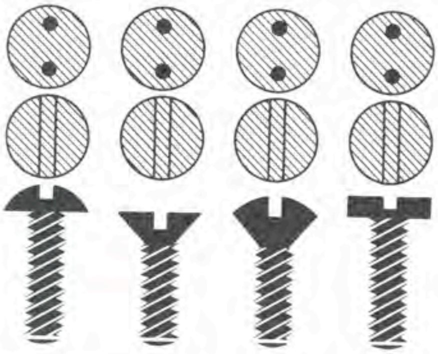
**III Holder with screw die**
1 stop screw
2 adjusting screw

**IV Taps**

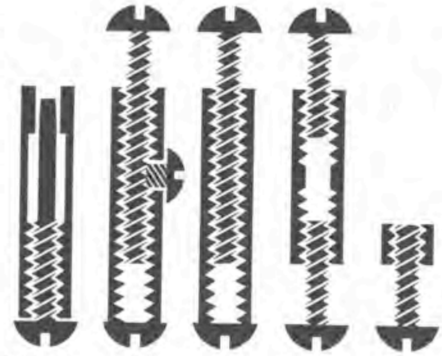
**V Tap wrench**
1 winding arm also serving as a stop screw

# 20 Screwing, riveting

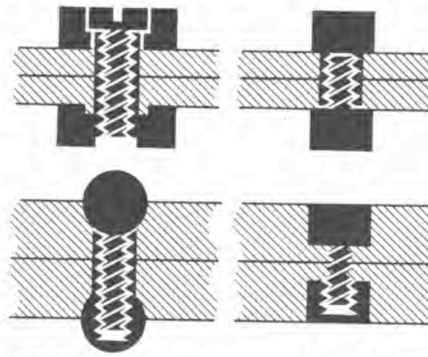
**Screws**



Screw heads

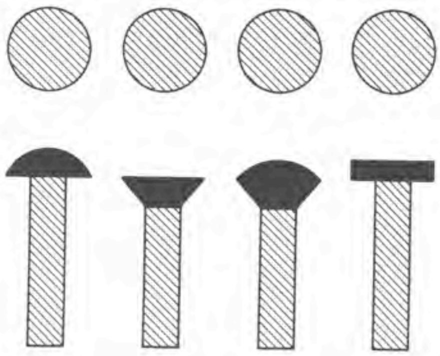


Screwing systems

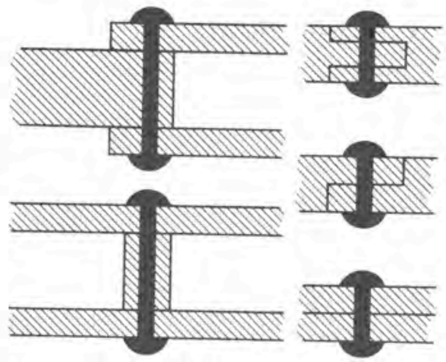


Screw types

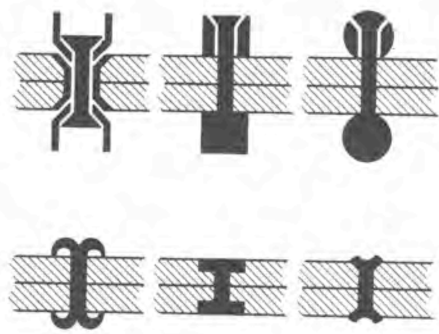
**Rivets**



Rivet heads



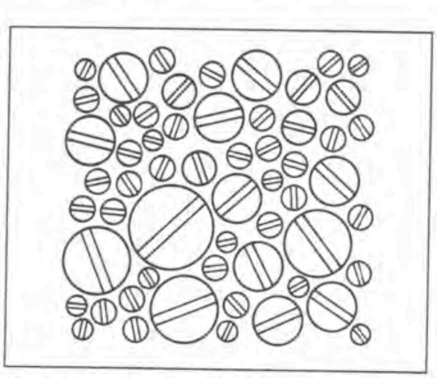
Riveting systems



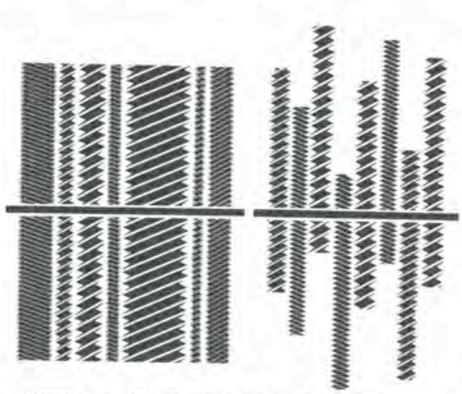
Rivet types

Observe:
- the different kinds of threads and their fields of application
- the thickness of screws or rivets in proportion to the load
- the difference between a running fit (freedom of movement of the two elements) and a press fit (fixing of the two elements)

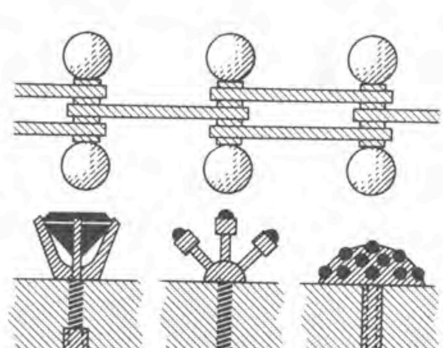
**Possibilities of creation**



Screw and rivet heads as visible elements



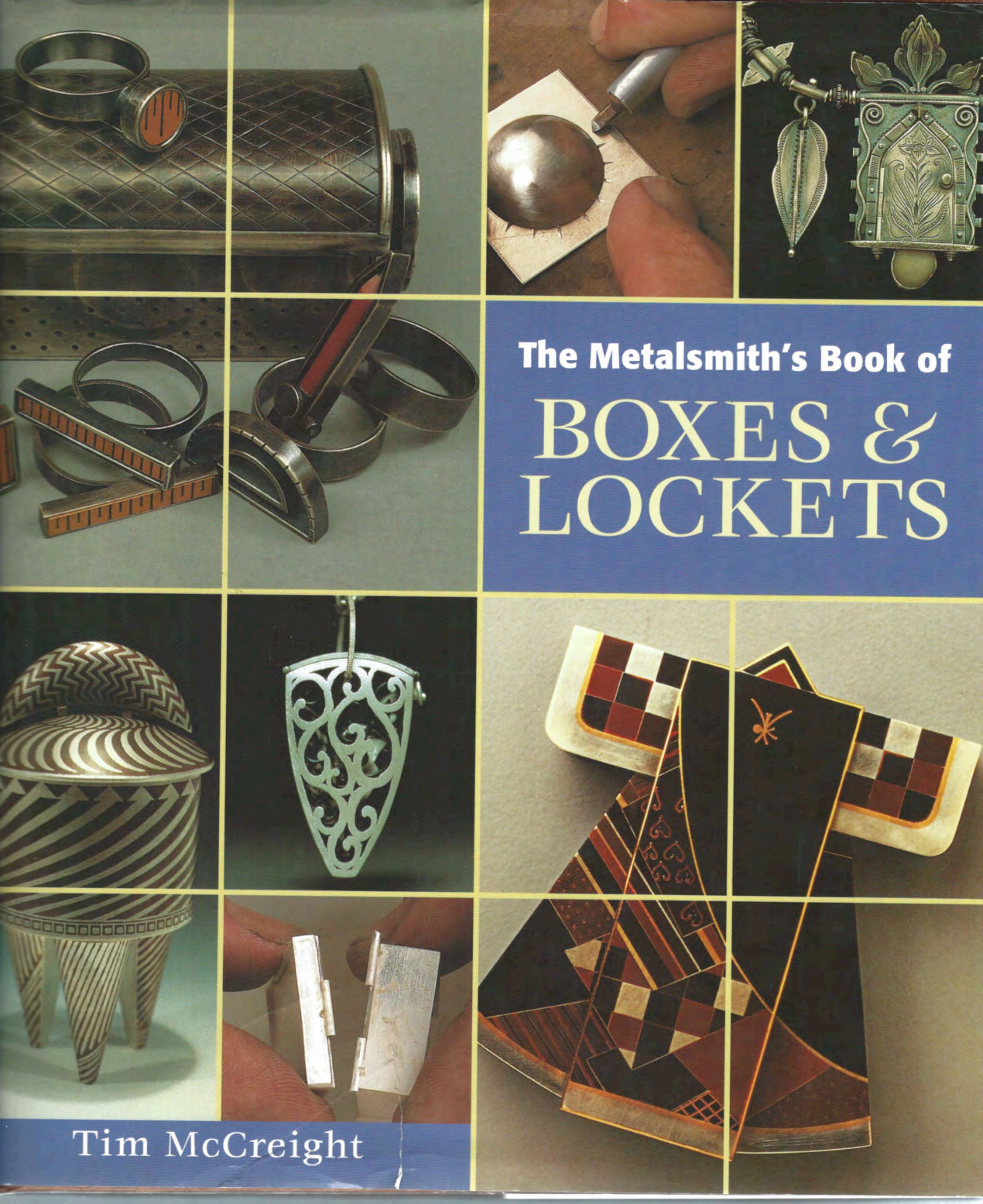
Threads as visible elements (structure)



Rivet or screw heads as supports for gems and pearls

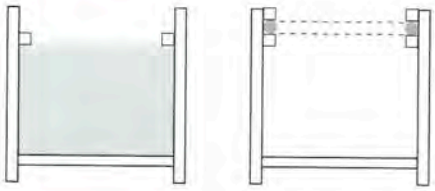
The Metalsmith's Book of

# BOXES & LOCKETS



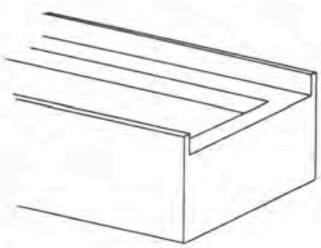
Tim McCreight

soldered? Well, maybe. This is a little risky because the box will expand slightly when heated and, at a



critical moment, the frame may tilt. Here's a simple way to avoid the problem.

Determine the correct height from the floor of the box to the bottom edge of the frame and cut thin sheets of copper or brass to exactly this height. Bend these strips into zigzags so they can stand up, and



set them loosely into the box. Press the frame down against these supports as far as it will go and proceed with the soldering. When finished, bend the strips as necessary to remove them. Then saw away a section of the wall at one end to make an opening for the lid.

A variation on this trick will be used to hold the second frame into place. Use graphite rod (pencil lead) to maintain an even spacing between the frames. This is where the lid will travel, so the gap between the frames needs to be a specific size. Purchase pencil leads from an office store, or cut away the wood from a standard pencil to uncover the graphite. Rub it on sandpaper as needed to achieve the desired thickness.

Set the graphite pieces into position (they can be held temporarily with a dot of glue if needed), then slide the second frame into place. Apply flux, lay solder chips along the frame and heat until the solder flows. Quench in water and pickle as usual; the graphite will probably fall out by itself. If it gets stuck, pick at it with a scribe to break it out.

Depending on the design of the box, the lid might have a handle or ornamental edge. The sliding action will be smoother if the edges of the lid are slightly rounded and polished.

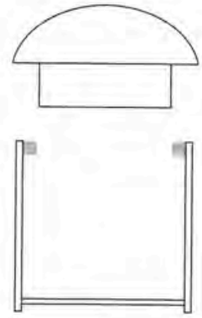
## Screw Closures

To better understand the mechanics of lids that tighten by rotation, step into the "Container Lab," also known as the kitchen. Look at the jars on your shelf and you'll see several variations on the closure shown here. For general use, let's start with the idea that the lid and container are round, or more correctly, segments of cylinders. It's possible to attach a cylindrical mechanism into a square box, for example, but for clarity of illustration we'll work on a cylindrical form.

### Bayonet Catch

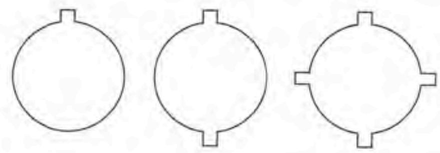
The bayonet catch can be used on all sorts of boxes and lockets, from large to small and simple to complex. The example shown here uses a basic version; innovative designers will quickly see ways to expand on the idea.

In this example, the container and lid were fabricated from sheet as described elsewhere. A rim was made from 14-gauge wire that fits snugly into the box. It's temporarily set into position inside the box, but not soldered yet. A bezel (an



interior wall that fits inside this rim) is soldered onto the lid so that it projects several millimeters into the box.

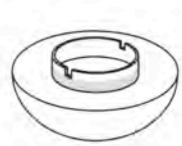
Small projecting tabs are soldered onto the underside of the lid to engage with the box. These are



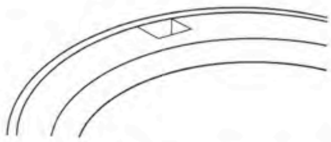
typically small pieces of square wire soldered onto the bezel, but many variations are possible. The catch works with one tab, but two, three or four will also work. If two or more are used, they should be spaced evenly around the lid.

In order for the catch to close tightly, the space between the lid and the top of the tab should be slightly less than the thickness of the rim, in this example, 14-gauge. One way to ensure the correct location of the tab—and location is important—is to saw a slot into the bezel into which the square wire is set. This makes careful checking easy and soldering foolproof.

Set the completed lid onto the box and mark the location of the tabs on the rim. Pull the rim out of the box and cut away a notch from

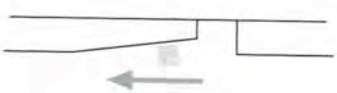


the outer edge, stopping short of cutting the rim into pieces. With a file, taper the lower edge of the rim slightly outward from each cut. If you work on one side only, the lid will be tightened by rotating in only one direction. If you file a



slope on both sides, the lid will tighten by twisting it in either direction.

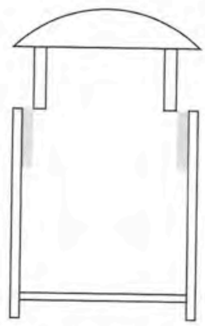
The rim is now soldered into the box, which can be pickled, rinsed and dried. Cut away the small bridge of metal that was hold-



ing the rim together—its job is done. File as necessary to allow the tabs to fit. When the lid is rotated, the tab slides along the slope on the lower edge of the rim, pulling the lid on tight.

## Making a Full Thread

In the previous example, the interior bezel on the lid made a snug fit into the rim. With a full-thread closure, there needs to be a space be-



tween the two elements. This is the space where the threads will be. The gap depends on the overall dimensions of the container; in this example, it's about 2 mm. The threads can be attached to the lid, the box, or both.

Think of a thread as a spiral ramp that climbs up the sleeve. It can be made of round, half-round, or square wire; round is easiest to bend but the others are easier to solder. Whatever you choose, wrap the annealed wire around the sleeve tightly, laying each rotation tightly against the preceding one. This will look as if you are wrapping a coil to make giant jump rings.

File the inside of the coil slightly to create a flat facet on the inside edge. This will make a strong joint when soldered onto the sleeve. To create a space between the threads, pull the coil apart. If you do this by holding onto the two ends, it will probably expand evenly. To check the consistency of the gap between threads, slide a piece of sheet—16-gauge in this case—along the coil. "Screw" the coil over the sheet; this will have the effect of making the space between the threads uniform.

Clean the container with Scotch-Brite and screw the coil into position. Apply small pieces of solder about every half inch along the track. Warm the piece uniformly, bringing the torch closer as needed to allow the solder to flow. Quench the piece in water, then pickle and rinse.

## A Simple Tab

Test fit the lid into the container. If it doesn't fit (and this is expected, so don't panic), file the thread to reduce its overall diameter. You'll see that this converts the round wire used in the thread into a flat thread that makes a tighter screw mechanism. Things are working out.

All that remains is to solder a tab onto the inside of the box. This

## A BAYONET CATCH

**1** Slots are cut in the inner sleeve to hold the wire tabs of this bayonet catch. The space between the lid and the tab (gray in the drawing) must be slightly smaller than the thickness of the rim that was soldered into the box.

**2** File a slope (or ramp) onto the rim, extending outward from the slot. This will create a friction that will lock the lid closed when it's rotated.

is nothing more than a short finger of metal that will slide along the threaded ramp until the cap is locked into the base. To make a clean and secure joint, drill a hole in the wall of the box, then fit a short length of wire into the hole for soldering. The size of this should match the gap between threads; in this example, it's 16-gauge. The wire is left at a comfortable length for soldering, then trimmed flush on the inside of the lid and cut very short outside. It is rounded slightly with sandpaper.

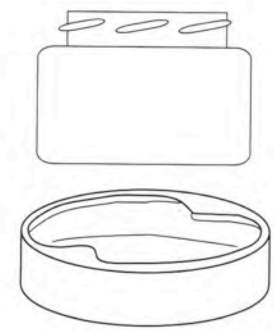
Test fit the pieces together, paying close attention to any areas of friction. File as needed to allow the top to screw smoothly onto the box.

## Making a Double-Threaded Closure

In this slightly more complex threaded closure, both units have a spiraling thread. Instead of a single metal post that travels along the thread, this construction has a full contact thread in both the container and the lid.

As in the first example, the container and lid need to have cylinders that allow space between them for the thread. To create the threads, lay two identical round wires side by side and wrap them in tandem around the sleeve. When you are done, unwind one from the other. Solder one onto the container and the other on the inside of the lid. This is a little easier said than done; expect some filing and fitting to make a proper fit. When soldering, take pains to heat evenly so the coils do not warp.

After the two sections have been quenched, pickled and rinsed, screw them together. If you're lucky, they'll fit at the first attempt. More often, the threads will need some filing to make them slide against one another.



## THREADED CLOSURES

**1** Screw the coil along a piece of metal to make the opening uniform.

**2** File the interior of the coil slightly to create a clean flat surface, then solder it onto the sleeve. To locate a tab accurately, drill a hole and force a bit of wire firmly into it. Trim to size after soldering.

**3** Use two wires held side-by-side to make a double coil. Here both sterling and brass are used, but usually the same wire is used for both parts.

### Variations

Go back to the kitchen and look at the jars on your shelves. In some cases, you'll see that the threads are three unconnected "ramps" along the sleeve. In others (baby food jars, for instance) you'll find that the catch on the lid is nothing more than a bend in the lip. Think of it this way: the Industrial Epoch has spent millions of dollars refining variations in which containers can be closed by a threaded device. You and I are the beneficiaries of that research.

Jane Campbell, *Box #897*, oval bracelet box. Sterling, 22K, 18K and 14K gold, opals, Chinese writing stones, apatite, mabe pearls, opal, onyx, tourmaline. A six-part box that contains four pieces of jewelry: a pendant on a 21" chain, earrings, and a bracelet. Facing page: the opened box.

# COMPLETE METALSMITH

Tim McCreight

# Threaded Connections

## Uses

Threaded mechanisms offer diverse attributes, often several at once. Threads provide:

- A low pressure grip for fragile and brittle materials.
- Removable cold connections that can facilitate repair and also allow owners to modify pieces.
- Tightening (sizing) mechanisms
- Closure for boxes, necklaces, and bracelets.
- A playful, potentially dramatic way to initiate movement.

### Dies Are Brittle

Dies are designed to cut away material between threads—do not rely on them to cut a rod down to size. These cutting tools are hardened and (in order to retain maximum edge cutting power) usually left untempered. This means they are brittle, so handle them carefully.

## Threaded Elements

The idea of an ascending spiral is credited to Archimedes, a mathematician who lived in Sicily in the third century BC. Anyone who has watched a moving spiral like an old fashioned barber's pole knows how powerful the attraction can be. Because screws, bolts, and jar lids are ubiquitous in modern life, we can easily forget their magic.

## *Thread Size*

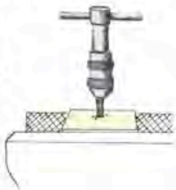
The two most common systems in the US are called National Coarse (N/C) and National Fine (N/F). Sizes are identified by two numbers, the first referring to diameter (or in small screws, a number from 2-12) followed by the counted threads per inch. Two common sizes, for instance, would be written as N/C 10/24 and N/F 10-32. These screws have the same diameter but the second one has finer teeth. The metric system is slowly gaining poularity here; in this system, threads are measured according to the diameter of the threaded shaft. There is only one pitch.

## *Taps and Dies*

There was a time when metalsmiths made their own dies, but today most workers find a trip to the hardware store more efficient. The tool that cuts an interior thread is called a tap and looks like a tapered screw with several channels cut along its long axis. Threading dies are used to cut threads on the outside of a rod or cylinder, and usually take the form of a thick steel disk with four holes in the center. Both tools are made with a specific size and pitch, which means that you must use a matching set.

### Tapping a Hole

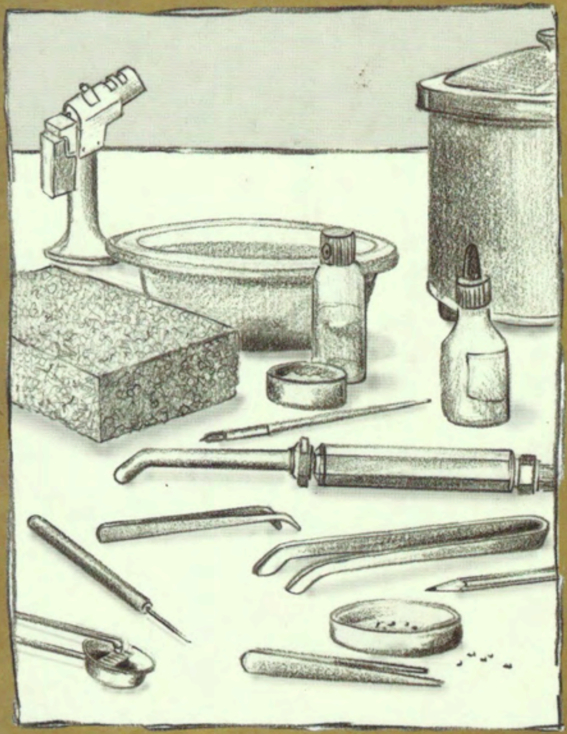
1. Drill a hole of the correct size. This is important: too large and the threads are shallow; too small and the tap might break.
2. Mount the tap securely in a handle and anchor the workpiece in a vise.
3. Hold the tap so it is perpendicular to the work, and screw it in until it bites into the metal. Add light lubrication and screw it half a turn further.
4. Reverse the action, unscrewing enough to clear the cuttings from the tap.
5. Screw in a full turn and reverse a half turn, continuing this rhythm until the tap no longer cuts.
6. Do not force the tool because it will easily snap. Add lubricant (any thin oil) and be patient. Allow the tool to do the work.



### Using a Threading Die

1. The diameter of the starting rod should be equal to the finished outside diameter of the threads. Roll, draw, or file as needed to get to this size. File a short taper on one end, then anchor the rod in a vise.
2. Grip the die in a handle and screw it onto the tapered end slowly. Rotate a full turn then unscrew a half turn to clear away the chips that were just cut.
3. Continue in this way—full turn forward, half turn back—until the die spins easily. Add a few drops of light oil every few turns to lubricate and wash away the chips.
4. It is important to keep the die perpendicular to the axis of the rod. When the rod is gripped close to the vise, the jaws provide a point of reference. If this is not the case, rig up a visual guide.

# Practical Joining



## A Bench Reference for Jewelers

Tim McCreight

## THREADED CONNECTIONS

The idea of a screw thread is traditionally assigned to Archimedes, a Greek mathematician. The relatively simple idea of a spiral confined along a cylindrical axis has had significant impact on our world, making possible everything from rocket ships to roller skates.

### Commercial Nuts and Bolts

#### Nomenclature

Screws and bolts are usually described by the diameter of the central rod and the pitch of the threads. In the United States, the two most common systems are the National Fine (NF) and the National Coarse (NC). In both these systems, the size is given by two numbers separated by a hyphen. The first number refers to the diameter of the rod (except for small screws) and the second is the threads per inch. For small screws, the diameter of the rod is identified with a number that (unfortunately) does not have any reference to its measurable size. These run from 0 (the smallest) to 10 (the largest number) before switching to inch fractions. See the charts on the following pages.

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### Using Commercial Nuts and Bolts

The most obvious way to use bolts is to simply insert the rod through the parts to be joined, then screw on a nut. Here are a few variations on the simple idea:

- Use two nuts to lock the joint. Turn the first nut along the rod until it is where you want it, then screw a second nut until it rests firmly against the first one. The result is that both nuts are locked in place.
- If you don't want the head of the bolt to show, solder the bolt onto the back side of a piece. If the head of the bolt will be in the way, cut it off and solder the remaining threaded rod onto the piece.
- Most bolt heads are hexagonal, a shape that allows for easy gripping with a wrench. When this shape is not consistent with the design, file the bolt head into another shape.

## SCREW AND TAP SIZES – INCH MEASUREMENTS

### National Coarse

| Tap | Drill |
|---|---|
| 0–80 | 3/64" |
| 1–64 | #53 |
| 2–56 | #51 |
| 3–48 | 5/64" |
| 4–40 | #43 |
| 5–40 | #39 |
| 6–32 | #36 |
| 8–32 | #29 |
| 10–24 | #25 |
| 12–24 | #17 |
| 1/4–20 | #7 |
| 5/16–18 | F |
| 3/8–16 | 5/16" |
| 7/16–14 | U |
| 1 /2–13 | 27/64" |
| 9/16–12 | 31/64" |
| 5/8–11 | 17/32" |
| 3 /4–10 | 21/32" |
| 7/8–9 | 49/64" |
| 1"–8 | 7/8" |

### National Fine

| Tap | Drill |
|---|---|
| 1–72 | #53 |
| 2–64 | #50 |
| 3–56 | #46 |
| 4–48 | #42 |
| 5–44 | #37 |
| 6–40 | #33 |
| 8–36 | #29 |
| 10–32 | #21 |
| 12–28 | #15 |
| 1/4–28 | #3 |
| 5/16–24 | I |
| 3/8–24 | Q |
| 7/16–20 | W |
| 1 /2–20 | 29/64" |
| 9/16–18 | 33/64" |
| 5/8–18 | 37/64" |
| 3 /4–16 | 11/16" |
| 7/8–14 | 13/16" |
| 1"–8 | 15/16" |

## SCREW AND TAP SIZES – METRIC MEASUREMENTS

### Metric Coarse

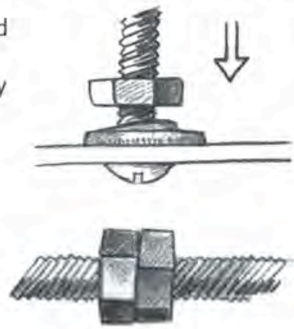
| *Tap* | *Drill* |
|---|---|
| 1 x 0.25mm | 0.75mm |
| 1.1 x 0.25 | 0.85 |
| 1.2 x 0.25 | 0.95 |
| 1.4 x 0.3 | 1.1 |
| 1.6 x 0.35 | 1.25 |
| 1.7 x 0.35 | 1.3 |
| 1.8 x 0.35 | 1.45 |
| 2 x 0.4 | 1.6 |
| 2.2 x 0.45 | 1.75 |
| 2.5 x 0.45 | 2.05 |
| 3 x 0.5 | 2.5 |
| 3.5 x 0.6 | 2.9 |
| 4 x 0.7 | 3.3 |
| 4.5 x 0.75 | 3.7 |
| 5 x 0.8 | 4.2 |
| 6 x 1 | 5 |
| 7 x 1 | 6 |
| 8 x 1.25 | 6.8 |
| 9 x 1.25 | 7.8 |
| 10 x 1.5 | 8.5 |
| 11 x 1.5 | 9.5 |
| 12 x 1.75 | 10.2 |

### Metric Fine

| *Tap* | *Drill* |
|---|---|
| 4 x 0.35mm | 3.6mm |
| 4 x 0.5 | 3.5 |
| 5 x 0.5 | 4.5 |
| 6 x 0.5 | 5.5 |
| 6 x 0.75 | 5.25 |
| 7 x 0.75 | 6.25 |
| 8 x 0.5 | 7 |
| 8 x 0.75 | 7.25 |
| 8 x 1 | 7.5 |
| 9 x 1 | 8 |
| 10 x 0.75 | 9.25 |
| 10 x 1 | 9 |
| 10 x 1.25 | 8.8 |
| 11 x 1 | 10 |
| 12 x 0.75 | 11.25 |
| 12 x 1 | 11 |
| 14 x 1.25 | 12.8 |
| 14 x 1.5 | 12.5 |
| 16 x 1.5 | 14.5 |
| 18 x 1 | 17 |
| 18 x 2 | 16 |
| 20 x 1.5 | 18.5 |

## Locking Washers

In threaded joints, it is possible for wear and vibrations to wiggle a nut loose. Wear that screwed-together brooch while you're dancing, and the parts might come undone. The solution is to put some pressure on the nut so it is less able to rotate accidentally. A typical locking washer is nothing more than a traditional washer that has been cut and bent out of a single plane. When the parts are screwed together, the twisted washer is compressed. It tries to return to its original shape, which is to say that there is pressure on the nut. This pressure locks the nut from casual turning.



A similar arrangement can be created with leather or rubber, both of which can be compressed by tightly screwing the nut down. After tightening, the washer expands, and again puts pressure on the nut.

## USING A TAP AND DIE

To cut threads, you will need tools called taps and dies. These are sold at hardware stores and jewelry supply companies, either singly or in sets. Both will require a specific handle or wrench, and while you can improvise if you need to, it's probably best to buy the appropriate tool. Assuming you will be making both the nut and the bolt (the positive and the negative), you'll need two separate tools that have the same size and pitch.

### Cutting External Threads

A threading die is a hard but brittle cutting tool, designed to cut away small portions of metal. It is important that you start with a rod that is very close to the eventual outside diameter of the threads, either by buying the proper rod or by filing it to the proper dimension. If there is too much metal to start with, not only will the process be slow, but the die is likely to break. To determine the proper starting diameter, either consult the chart here, or use the shaft of the tap as a guide. The starting rod should have the same diameter as the bottom, unthreaded, section of the tap.

1 Select a rod of the proper diameter and file a shallow taper on the end.

2 Secure the rod in a vise, preferably either straight up or straight out. If this is aligned with the jaws of the vise (as opposed to angling off randomly), it is easier to keep the die straight.

3 With the die in a handle, screw it onto the tip of the rod until it engages. Screw one full turn, making sure the die is level. Unscrew a half turn.

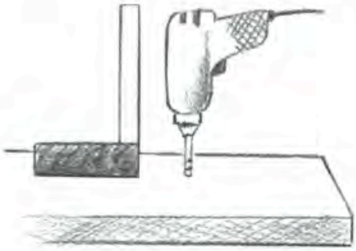
4 Screw a full turn ahead, which means only the last half of the turn is cutting. Unscrew to allow the chips to fall away and screw forward, only cutting for about half a rotation. Continue this full turn forward/half turn back pattern until the threads are as long as you need. It's helpful to add a drop of light oil every couple of turns to lubricate the process.


---

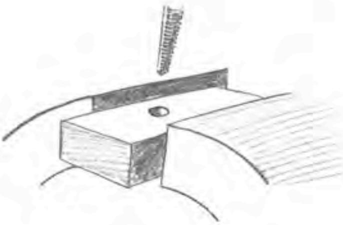
**Cutting Internal Threads**

This process is very similar to cutting threads on a rod. Prepare the metal, use a forward-and-reverse motion, and take your time. Again, the tool, called a tap, is a hard but very brittle steel part that is designed only to cut away small bits of metal. It is very important that you start with a hole the right size. Some taps have the recommended drill size stamped on the shaft of the tool, and many kits have a chart attached to the box. The same charts are given here on page 19 and 20.

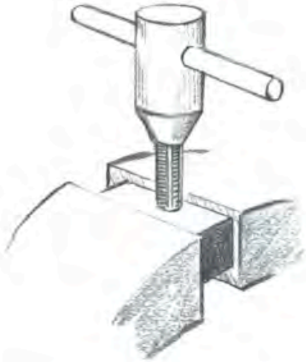
1 Drill a hole of the proper diameter, squarely through the metal. A drill press is best for this, because it maintains the bit at 90°. If you are using a hand drill, set a vertical line behind the work and use it as a point of reference. This could be a try square, a plumb line, or even a book.



2 Secure the piece in a vise, unless it's large enough to stand on its own. If possible, line it up symmetrically in the vise so you can use the edges of the vise for visual reference.



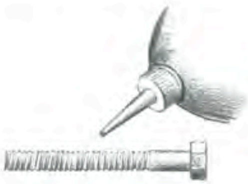
3 Screw the tap into the hole until it just engages, then go a half turn forward. Reverse the motion to clear the threads. Place a drop of light oil onto the tap and screw it in another half turn forward. Reverse, then go forward, always stopping as soon as you feel a drag on the tool. If the chips do not fall away by themselves, unscrew the tap periodically and wipe the waste off on a rag. Continue until the tap moves easily, which indicates that it is no longer cutting.



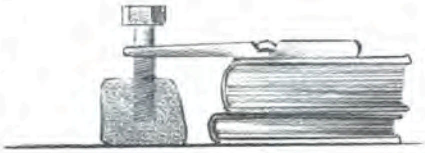
## Making Threaded Parts by Casting

If you need a 14k gold bolt (hey, it could happen), one solution is to attach a sprue to a plastic bolt, invest it as usual, then go through the process of burnout, casting, and cleanup just as you would for any other casting. It is more likely, though, that if you are casting elements that will be joined by threaded connections, that you want the threads to be integrated into the design.

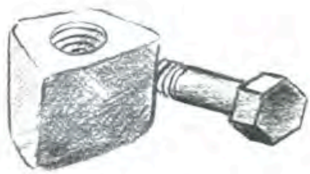
1 Apply a thin layer of oil on a steel or brass bolt. This can be any light oil, including 3-in-1, WD40, mineral oil, olive oil, or motor oil.



2 Warm the bolt in a lamp or torch flame until it is just barely too hot to hold. Insert the heated bolt into a block of wax, holding it as straight as possible. To allow the wax to harden onto the bolt smoothly, the parts must be stable. Rig up a Third Hand or similar arrangement so you can set the parts aside, untouched, until the wax hardens.



3 Leave it for at least ten minutes, then gently unscrew the bolt. Examine the interior threads you've made in the wax to be sure they are clean and intact. If not, repeat the process with a fresh block of wax; it's better to make it right than to invest time in carving and casting a piece that you know is faulty.



4 Dribble a few drops of oil into the threaded hole to deposit a thin lubricating film on the threads you've just made. Shake off any excess oil.

5 Build up a cup with tape around the opening of the threaded hole. This funnel makes it easier to pour melted wax into the hole but, and equally important, the lump of wax here will be a handle that will make it possible to unscrew the rod you are creating. Melt a rigid wax in a can or a spoon, and pour it into the threaded hole.

6 Wait at least ten minutes, then gently unscrew the threaded rod. You can now carve these wax elements as needed.

7 Spruing, investing, and casting proceed as for any other casting, with these commonsense concerns:
- Do not attach a sprue to the threads.
- In order to guarantee that no air bubbles form on the threads, mix a small batch of thick investment and paint it onto both threaded portions. Flow the investment gingerly off the brush, troweling it on to avoid trapping bubbles.

---

## Making Threaded Parts with Metal Clay

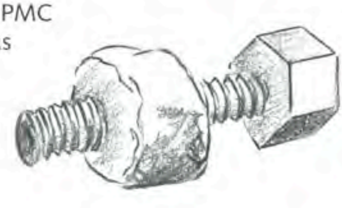
This process is similar to casting, except that it allows you to skip the spruing, investing, and burnout steps. Metal clay is only available in silver and gold, so brass and bronze threads are not an option here.

Making Internal Threads

1 Lightly oil the threads of a bolt. Press PMC around a shaft, making sure that it has complete coverage.

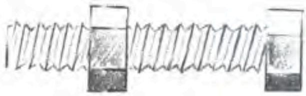
2 Allow to dry completely.

3 Unscrew the bolt gently.

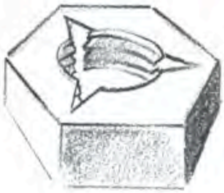


Making External Threads

1 Make a thread cutting die from a standard steel or brass nut. Remember that the resulting threaded rod will be a little smaller than the nut because of the shrinkage of PMC.

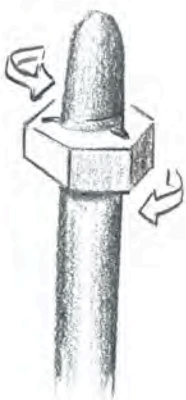


2 File three V-shaped notches on the interior of the nut. These will expose edges that will cut the threads.



3 Make a rod of PMC+ or PMC3, slightly larger in diameter than the hole in the nut. Roll it so one end tapers slightly. This will make it easier to start the cutting process. Allow this to dry completely.

4 Screw the nut gently onto the PMC rod until it engages and starts to cut. Unscrew to clear the material, then turn the nut another full rotation. Continue this screw-unscrew action until you have cut all the threads you want. Work over a piece of paper so you can retrieve the dry PMC scraps. These can be rehydrated and reused.



*This issue's tech article brings me back to my Grad-school days, when mechanisms and cutting my own threads for nuts and bolts held my interest. I used Sears' store bought taps and dies and puzzled my way through by using the charts that came with the set to select drill bits and wire sizes. Pat Nelson does an excellent job at unraveling the mysterious measuring systems for screws. Enjoy.*

# THE MEANING OF SCREWS

(The nuts and bolts of the subject)

By Pat Nelson, Ball State University

Last summer, I conducted a workshop in enameling on 3 dimensional forms for a group of Washington DC enamellists. An important technical aspect of such enameling is how to connect these enamels to other forms. The methods of connection such as bezel setting, which work on relatively flat enamels, are not appropriate to highly dimensional enamels. However, one excellent connection method is using screws and nuts, either manufactured or handmade. For examples of manufactured connections, I brought 2-56 x 3/8 hex screws with me, along with 2-56 hex nuts.

What this means is:

1. The easy part—the screws—were 3/8 inch long. You can get these screws in lengths ranging from 1/8, 3/16, 1/4, and 3/8, to 1/2 inch long.
2. The second easiest part is the head type, the shape of the top. These shapes are hexagonal, flat (which is good for countersinking), round, which is domed, and fillister, which is a kind of a medicine tablet shape.
3. Now comes the harder part—just what does 2-56 mean? See below:

Metalsmiths and jewelers made bolts and screws long before the standardization of weights and measures made possible by the industrial revolution. Until the 1940s there were myriads of sizes and scales, none of them matching up with one another. During WWII, the American government needed to standardize parts made by all the Allies. After WWII, the NATO countries synthesized the most prominent systems into the Unified Thread Standard and the Unified Miniature Series (UNM). The table below refers to the UNIFIED THREAD STANDARD, still the best understood standard for jewelers, model makers, sheet metal workers, etc. In fact, Lowes has very nice brass screws and hex nuts in the larger sizes, for example: 6-52 and 8-32. In these systems, screws (or bolts – there is no official defined difference) come in the following numbers useful for jewelers and metalsmiths (they are NOT metric, they are still based upon inches). Each of these nut / screw sizes is followed by a designation; either UNC, which means Unified Thread Standard Coarse, or UNF, which means Unified Thread Standard Fine. In general, the coarse sizes have fewer threads for the size of the diameter than the fine. In the sizes smaller than 0-80, the designation NS is used, meaning the old pre war National Thread standard.

| | | | | |
|---|---|---|---|---|
| 0000-160 NS | 0-80 UNF | 2-64 UNF | 4-48 UNF | 8-31 UNC |
| 000-120 NS | 1-72 UNF | 4-36 UNS | 6-32 UNC | 8-36 UNF |
| 00-90 NS | 2-56 UNC | 4-40 UNC | 6-40 UNF | 10-32 UNF |

The larger number (the 56 in 2-56) denotes the number of threads per inch. The smaller number (the 2 in 2-56) denotes the maximum width of the screw body, including the threads. The system is rather indirect but if you take 0 (as in 0-80), that 0 stands in for .060 of an inch. As you go larger, add 13 thousandths of an inch, so the body of the screw in a 1-72 screw is actually 73 thousandths (.073) inch. My 2-56 screws are 86 thousandths of an inch in diameter, with 56 threads to the inch. Similarly, as you double up on 0s, you subtract .013, so a 00-90 screw is 47 thousandths of an inch in diameter, with 90 threads to the inch.

(For this information I thank John Dirlam from J I Morris Co.)

In order to really use this information, you need to know what tap drills and body drills are. If you intend to make your own nuts and screws, as is done by many silver and goldsmiths, you need information on drill bit and wire size.

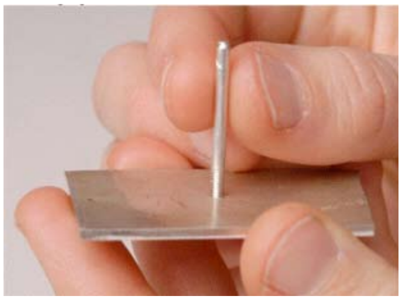
For making nuts and screws, you need a TAP and DIE set, obtainable in the abovementioned sizes (for information on another system, the Colibri Swiss metric system, see additional instructions). The tap cuts internal threads into a previously drilled hole in a piece of metal (made by the Tap drill) thus making a nut, while the die cuts threads into a rod or wire, making the screw or bolt. For a reliable connection, it is recommended that the metal for your nut is thick enough to contain at least 3 levels of thread. The body drill will drill a hole that will allow the threaded screw to pass through snugly, but will not damage the threads. If you intend to connect 2 pieces of metal with a nut and screw, drill the metal pieces with the body drill. The screw will pass cleanly through the pieces to be fastened together. Refer to the following chart for screw sizes, tap drills, body drills, and wire / rod sizes. The rod / wire sizes indicate what size wire you should thread to make a screw in that size

| Screw | Tap Drill | Body Drill | Rod / Gauge |
|---|---|---|---|
| 00-90 | #62 | #56 | .046" / 18G – 17G |
| 0-80 | #55 | #52 | .059" / 16G – 15G |
| 1-72 | #53 | #49 | .072" / 13G |
| 2-56 | #50 | #48 | .085" / 12G – 11G |
| 2-64 | #50 | #48 | .081" / 12G |
| 4-40 | #43 | #33 | .110" / 9G |
| 4-36 | #43 | #33 | .110" / 9G |
| 4-48 | #42 | #31 | .112" / 9G |
| 5-44 | #37 | #29 | .125" / 8G |
| 6-32 | #36 | #28 | .136" / 8G |
| 8-32 | #29 | #19 | .162" / 6G |

These gauge sizes are close, yet still approximate. Essentially, the thousandths inch system and the B&S / AWS gauge do not correspond perfectly, and most dealers who sell precious metal (silver or gold) wire only sell in even number B&S gauges, i.e. 10G, 12G, 14G. I'd experiment with the closest thing, but if you have a drawplate, you can draw down one hole if the wire is too thick to thread, or use slightly thicker wire or rod if your thread is too loose. For example, if you use the 0-80 die, 16G is slightly small, and 15G is slightly large. If you have access to wire drawing equipment, you might obtain a wire exactly .059, but you would need calipers to be that exact. Rio Grande does sell a wide variety of both dial and electronic calipers at a range of prices, starting at @ $20.00. Some metalsmiths routinely use one size larger wire gauge for the screws, and one size smaller drill bit for the nuts than is officially recommended, especially when using non-ferrous metals instead of steel.

Small tap and die sets are available at most jeweler suppliers, but you need to know what system you are getting (see info on Rio Grande). Reactive Metals sells a smaller tap and die set ranging from 00-90 to 2-56. Sets larger than that, as well as larger individual taps and dies, are available at hardware stores. You need holders for the taps and dies. For a tap, a tap holder or a pin vise will work. There are two types of dies, the individual die that needs a die holder, or a screwplate that has several different sized dies on one rectangular shaped steel piece. The individual dies are always best, but you can have numerous dies at hand with a screwplate.

**When making a nut:**



1. Make sure your sheet metal is thick enough to hold at least 3 levels of thread. Any less than that and the nut will not hold. If you are making multiples, or if your nut is quite small, drill and tap into a larger piece, then cut the nut out.

2. Drill hole with the tap drill. Make sure you are drilling straight into the metal at a perfect 90-degree angle. Use a drill press if possible.

3. Use a tap holder, pin vise, etc… to hold the tap. SCREW IT INTO THE HOLE PERFECTLY STRAIGHT! Screw down twice, and then unscrew two full turns. This will release the metal shavings created when cutting the threads. Use a lubricant or a cutting fluid. A light oil will work, but you can purchase oils specifically for cutting / milling.

Tap inserted in holder, ready to thread hole drilled with appropriate tap drill

This image shows the tap cutting threads. The position is critical - the tool is held perfectly perpendicular to metal sheet being threaded. Use cutting fluid when cutting both the nut and the screw.

**When making a screw:**

1. Insert wire or rod upright into a vise. MAKE SURE IT IS STRAIGHT!

2. Taper the tip of the wire. This is critical for proper attachment of the die. Make sure the die is set onto the metal perfectly straight. Do the same here as with the nut – make two turns down and two turns back. This will release shavings from the wire. Again, use a cutting fluid.

3. Cut the wire at whatever length you need and solder it to your work or to another shape for a head. When making your own nuts and bolts, you can have whatever head / bolt design you want for your piece. It is much easier to make a component just specifically for your piece if you are making your own.

Rio Grande sells a Colibri tap and die set. This is a Swiss metric set that has nothing to do with the Unified Thread system. However, it allows for very small screws and nuts, and a wide assortment of sizes at this small scale. The following information will allow you to use it.

Things you need to know about the Colibri set from Rio Grande:

| Tap size | Tap Hole | Drill Bit | Wire |
|---|---|---|---|
| .8mm | .6mm | #73 | 20G |
| 1.0mm | .75mm | #69 | 18G |
| 1.2mm | .9mm | #65 | 17G |
| 1.4mm | 1.05mm | #59 | 15G |
| 1.6mm | 1.2mm | #56 | 14G |
| 1.8mm | 1.35mm | #55 | 13G |
| 2.0mm | 1.5mm | #53 | 12G |

This set comes with a screwplate, not individual dies. The holes are numbered 20, 18, 16, 14, 12, 10, 8, and 6. These numbers DO NOT REFER TO WIRE GAUGE SIZES. They refer to the tap mm sizes, so the holes marked 20 correspond to the tap size 2.0, the holes marked 18 correspond to the 1.8 tap etc. The holes marked 12, 10, 8, 6 are in multiples, while those marked 20–14 have one slotted hole and one plain hole. These holes are, of course, threaded. To use the screwplate, place your wire straight up in a vise, taper the tip, and attach the screwplate. Turn twice, and then back off one turn, just like using the standard individual dies. Be sure to use a cutting fluid. The screwplate is slightly more difficult to twist straight, and it is much thinner that a standard individual die, so it is just plain harder to use. It is recommended you keep the numbered side of the screwplate up while working.

(For this information, I thank Mark Nelson from Rio Grande)

This image shows the Colibri screwplate cutting threads on a wire. It is important to maintain this screwplate absolutely perpendicular to the wire.

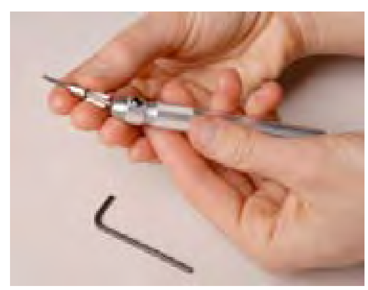
When soldering a screw or a piece of threaded wire onto a piece of metal, I coat the majority of the length with typing WiteOut. This keeps the solder from climbing onto the threads.

*(Editor's note: Another trick you can use for soldering when you must get just the right amount of solder and avoid excess flowing where you don't want it to. Using a scrap piece of nickel, flow your solder onto it in a very thin layer. Just touch the end of the screw to the molten solder while you gently heat with your torch. The amount of solder transferred to the screw end should be just the right amount to do the job and not flow up the threads. I have used this technique to solder bezel wire onto etched pieces with no solder flowing into the etched areas. I also recommend using an anti-flux on the threads for added safety.).*

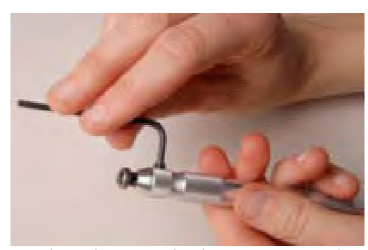
**Below are images of some of the tap and die sets described in this article.**

This shows the Colibri set. A tap is held in a pin vise (which is not included in the set)

This shows the Unified Thread Standard set sold by Reactive Metals. The handle holds both the taps and the dies. The sizes in this set range from 00-90 to 2-56



This shows a tap being inserted into the handle



This shows a die being inserted into the handle included in the Reactive Metals set

Typical set that can be purchased at a hardware store.

Taps in two styles of tap holders

Individual die, and die in holder

**SOURCES**

**J. I. Morris Co., 394 Elm Street, Southbridge, MA 01550, 508.764.4394, www.jimorrisco.com**
This is the gold standard for all your miniature screw needs. I purchase my brass 2-56 sets by the gross. The screws come separately from the nuts. They have very comprehensive charts on their website. They sell brass and stainless steel nuts and screws, as well as threaded rod so you can cut your own lengths of screws. Morris sells a small thread chart (mini-thread database) rather like a slide rule, which contains lots of engineering information for $14.99.

**Rio Grande, 800.545.6566, www.riogrande.com**
Rio has the Colibri tap and die set I described that is based on a Swiss metric scale. It is also the ultimate jewelers' tool, supply, metal, findings, and gem superstore. Rio also sells a variety of calipers so you can measure the exact diameter of your metal rod or wire.

**Reactive Metals studio, 928.634-3434, www.reactivemetals.com**
They sell nuts, screws (bolts) and washers made from brass, or you can buy brass nuts/screws plated with silver, gold or black oxide. They sell the jewelry standard sizes – 00-90 to 2-56. They also carry threaded rods, plus the tap and die set described in the article.

**Small Parts, 800.220.4242, Fax 800.423.9009, www.smallparts.com**
More limited selection of nuts / bolts than Morris, but they have lots of other wonderful things to offer.

**Metalliferous, 34 W. 46th Street, NY, NY 10036, 212.944.0909; Mail order, 888.944.0909, info@metalliferous.com.**
Sells nuts and bolts, as well as assorted taps and dies.

**Frei and Borel, 800.772.3456, www.ofrei.com**
They sell the Colibri set—same as Rio. They also sell very high quality, very expensive taps and die manufactured for watchmakers.

**Lowes, Sears, Menards etc., Anytown, USA**
Again, they sell tap and die sets, plus individual taps and dies in the larger sizes. It would be rare to find anything as small as 2-56 in any of these places, but they have lots of choices of the bigger sets. They also carry very nice brass machinist screws and nuts in larger sizes, i.e. 8-32. If you solder screws to your work, be careful to select solid brass. Brass plated steel will make a mess in the pickle.

Thanks to Serena Nancarrow for photos.

*Keep sending me your ideas for tech articles. Whether you want to tackle the subject, or are looking for another hearty soul to take it on. Your contributions make this possible.*

*Looking forward to hearing from you, Jim Bové, <jimbove@hotmail.com>.*

*SNAG News* will pay up to $125 per page (up to 4 pages) for informative technical articles aimed at any level—from intermediate to advanced, from student to the highly skilled professional. If you teach a workshop, have a clever bench trick or technique of interest to other jewelers and metalsmiths, or have more academically based technical research, please share it with our SNAG community.

Send your submission to
Jim Bové, 1497 Route 136, Washington, PA 15301,
jimbove@hotmail.com

# UNIT 13

# Characteristics, Tools, and Hand Tapping Processes of Internal Threading

Technical knowledge about the screw thread was recorded by the scientist Archimedes over 2,000 years ago. From that time until the Middle Ages, Roman, Greek, Arab, and other civilizations designed, hand-produced, and applied screws. As shown in the layout in Figure 13–1, screws were formed from a thread outline drawn around a cylinder. Then, by following the outline, grooves were sawed and filed. Hardwood was used as the basic material. Later, when metal armor was introduced, its bolts and nuts were handmade of metal.

The introduction of movable machines like the printing press brought the need for components made of metal. Some parts in these machines were activated (moved) by metal screws. Other parts that had to be fastened and held together securely also needed metal screws. The growing demands of industrialization brought on demands for developmental work to produce screw threads faster and more accurately with machines.

This unit begins with a brief historical review of important milestones in screw thread design, development, and standardization. This unit also deals with:

—Functions and characteristics of screw threads,
—Cutting tools and accessories for internal threading by hand,
—Actual hand tapping processes.

Later units cover more advanced technology and precise machine methods, tools, thread fits, and thread forms. Thread formulas and other computations are treated as they relate to machine setups and processes.

## HISTORICAL SCREW THREAD DESIGN AND MANUFACTURING DEVELOPMENTS

A number of Leonardo da Vinci's design sketches around the year 1500 provided technical information about and showed the features of a screw-cutting machine. Twenty years later the French inventor Besson was credited with developing the first foot-operated lathe spindle. This lathe was used for chasing (cutting) threads with a combing tool.

The first breakthrough in the production of wood screws came in the mid-1700s. A mechanized factory was started by the Wyatt brothers of England. They mass-produced 100,000 wood screws a week.

Steam power and the Industrial Revolution brought about a period of greater efforts toward the design and accurate reproduction of master screws, or lead screws. Lead screws were needed to produce other forms and sizes of screw threads. During this period, after years of laboriously designing, forming, and testing, Henry Maudslay produced the first all-metal screw-cutting lathe in England. His lathe effected the development of a lead screw that was extremely accurate for its time. It had an error of 1/16″ in its length of 7′. Because of its accuracy this lead screw became a master for producing other lead screws. During most of the 1800s, screw threads were cut on lathes by single-point chasing tools, thread-cutting dies, and thread-combing tools. In 1887, an important cutting tool development took place. A.B. Landis introduced a self-opening thread-cutting die head in the United States. This development further revolutionized thread cutting and the mass production of threaded parts.

The advances in screw thread design and manufac-

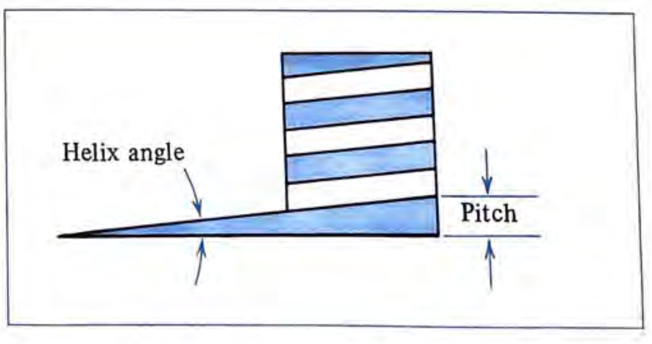



**FIGURE 13–1** Early Layout of a Screw Thread

ture created national needs for thread standardization. Within the United States a Franklin Institute committee in 1864 recommended a system of screw thread standards. These standards were largely developed by William Sellers. He improved on the earlier work of Sir Joseph Whitworth of Great Britain. Sellers modified the sharp crest and root of a 60° V form by introducing a more practical flat crest and root. It should be noted that modifications of the screw thread standards established by Whitworth in 1841 became the basis of the British Standard Whitworth (BSW) thread.

By 1868 the Sellers Standard was adopted as the United States Standard (USS). The USS system was excellent for coarse threads. However, with industrial expansion, new machines and mechanical movements, and the later demands of the evolving automotive, aircraft, and instrumentation industries, a finer thread series was needed. The work of the Society of Automotive Engineers (SAE) on a fine-thread screw series was adopted in 1911.

## FOUNDATIONS FOR THE AMERICAN NATIONAL AND UNIFIED SCREW THREAD SYSTEMS

The two systems, USS and SAE, provided standards for form, pitch, and outside diameters. Nevertheless, further standardization and improvements were needed. The National Screw Thread Commission of 1918, together with the SAE, the American Standards Association (ASA), the American Society of Mechanical Engineers, and other professional groups developed the original *American National Screw Thread Standards*.

The new standards included different tolerances, clearances, and other improvements. They provided flexibility in thread forming and manufacturing. American National Screw Thread Standards included the coarse-thread series of the USS and the fine-thread series corresponding to the SAE. By 1935 the American Standards Association approved these standards, which later became the National Coarse (NC) and National Fine (NF) series.

Although efforts to standardize were carried on notably by Great Britain, Canada, and the United States, threaded parts among these countries were not interchangeable. The British Whitworth thread had a 55° standard thread angle; the United States, a 60° standard. Finally, in December 1948 the systems of these countries were standardized into the *Unified Screw Thread System*.

The Unified thread system is a compromise between the British and the American systems. The design of the new thread form (shape) is such that parts threaded to conform in shape to either the National Coarse or National Fine series are interchangeable with British parts. The British preference for the feature of a rounded crest and root is incorporated in the Unified system. This feature is important in mass production and the life of a screw thread.

## THE INTERNATIONAL (ISO) METRIC THREAD SYSTEM

Paralleling developments in the Unified and American National systems were international movements. These movements were designed to modify the many European metric thread systems into an internationally accepted, single metric system. The result was the international metric thread form established by the *International Organization for Standardization*, known as *ISO*. This metric standard thread form is used in Europe and in many countries throughout the world.

The ISO thread form is similar to the Unified and the American National forms, except for three basic differences:

—The depth of the thread is greater,
—The sharp-V thread form is flattened at the crest to one-eighth of the thread depth,
—The root is flattened (with a rounded root preferred) to one-eighth of the thread depth.

The ISO form is the foundation of the ISO metric screw thread series.

There are still many problems to be resolved among the Unified, American National, and ISO Metric thread systems. Each system still includes a considerable number of pitch combinations in relation to diameters (pitch-diameter) in both the coarse-thread and fine-thread series.

The *Industrial Fasteners Institute (IFI)*, after considerable worldwide research, has proposed a single pitch-diameter series of 25 metric threads. When adopted, the IFI system may reduce and replace many of the 59 standard Unified and 66 standard ISO Metric pitch-diameter combinations. These combinations are now in the Unified and American National systems for the coarse-thread (UNC and NC) and fine-thread (UNF and NF) series, as well as in the ISO series.

## INTRODUCTION TO SCREW THREADS

### Basic Thread Producing Methods

Eight basic methods are employed to produce threads. The threads meet high standards of form, fit, accuracy, and interchangeability within a thread system. The eight methods are:

—Hand cutting internal threads with taps and external threads with dies;
—Machine tapping using formed cutters;
—External and internal machine thread cutting with single-point cutting tools;
—Machine threading using multiple-point cutting tools;
—Machine milling with rotary cutters;
—Machine grinding with formed abrasive wheels;
—Machine rolling and forming;
—Casting, using sand, die, permanent mold, shell casting, and other techniques (one unique advantage of the casting method is that parts of some machines—for example, sewing and vending machines, typewriters, and toys—have internal threads cast in place).

## The Nature of Screw Threads

A *screw thread* is defined as a helical (spiral) ridge of uniform section (form and size). This ridge is formed on a cylindrical or cone-shaped surface. The basic features of a screw thread are illustrated in Figure 13–2. Screw threads that are produced on an outer surface, like the threads on bolts and threaded studs, are called *straight external* threads. Screw threads that are cut on cone-shaped surfaces, like pipe threads, are *tapered external* threads. Threads that are cut parallel on inner surfaces, as are the threads of an adjusting nut or a hexagon nut fastener, are known as *straight* or *parallel internal* threads. External and internal parallel threads are referred to in shop language as just *outside* threads or *inside* threads.

Some threads may be advanced (moved) or tightened into a part by turning them clockwise. These threads are classified as *right-hand* threads. Threads that advance when turned counterclockwise are *left-hand* threads. Right- and left-hand threads each have special applications. Unless otherwise indicated on a drawing, the thread is assumed to be right-hand.

## Functions Served by Screw Threads

Screw threads serve four prime functions:

—As fasteners to hold two or more parts securely in a fixed position and to permit assembly and disassembly;
—As simple machines (in a physical science context) to transmit and increase force or power (a machine feed screw and a common screw jack are shown in Figure 13–3 as examples of this function);
—As design features on measuring instruments (such as a threaded spindle of a micrometer) to produce motion (precise measurement standards may be established by this motion);
—As mechanical devices to change a rotary motion to a straight-line motion (Figure 13–4 shows a feed screw being turned to raise or lower a machine table).

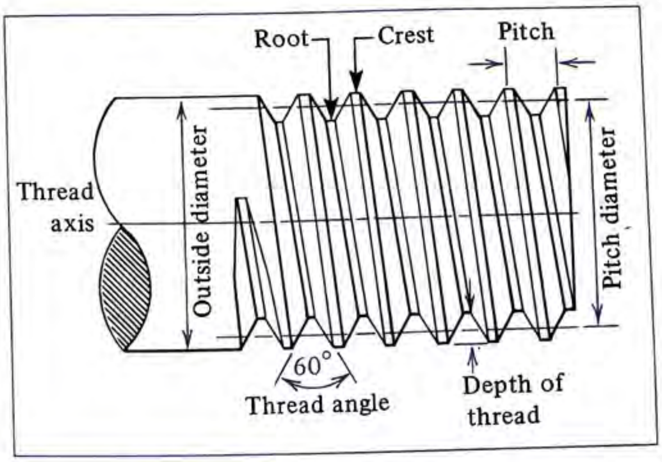



**FIGURE 13–2** Basic Features of a Screw Thread

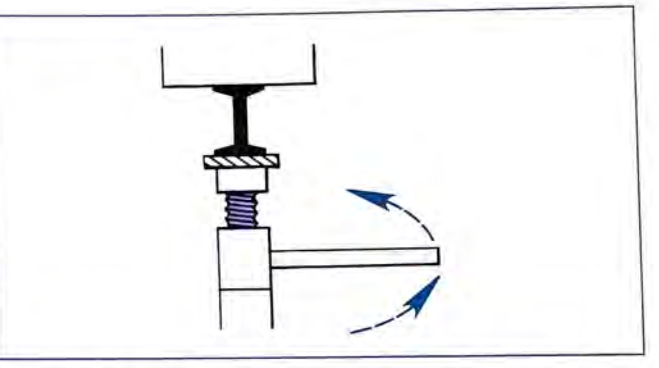


**FIGURE 13–3** Increasing Force with a Screw Thread

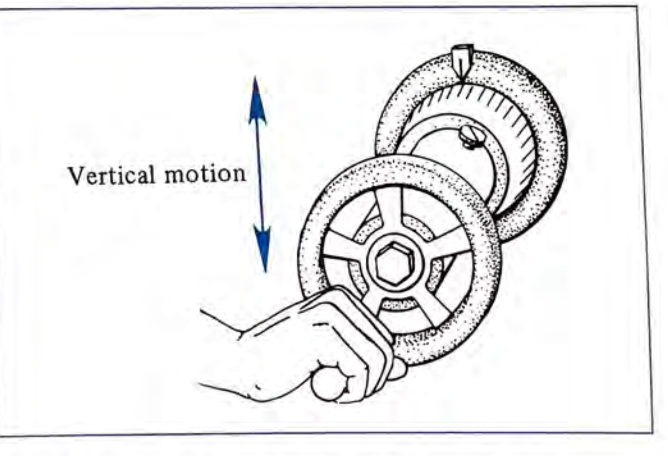



**FIGURE 13–4** Changing Rotary to Linear Motion with a Screw Thread

**TABLE 13–1** Selected ISO Metric Thread Coarse Series (2–24mm)

| *Outside Diameter (mm)* | *Pitch* | *Tap Drill Diameter* |
|---|---|---|
| 2 | 0.4 | 1.6 |
| 2.5 | 0.45 | 2.1 |
| 3 | 0.5 | 2.5 |
| 4 | 0.7 | 3.3 |
| 5 | 0.8 | 4.2 |
| 6 | 1.0 | 5.0 |
| 8 | 1.25 | 6.8 |
| 10 | 1.5 | 8.5 |
| 12 | 1.75 | 10.3 |
| 16 | 2.0 | 14.0 |
| 20 | 2.5 | 17.5 |
| 24 | 3.0 | 21.0 |

## AMERICAN NATIONAL AND UNIFIED SCREW THREADS

Each thread has a shape, or profile. This shape is called the *thread form*. Although the size of a thread form varies according to the dimensions of a threaded part, the shape remains constant. The symbol U preceding a thread form on a drawing indicates that the shape conforms to Unified system standards and is accepted by Great Britain, Canada, and the United States.

There are four basic thread series and one special thread series in both the Unified thread system and the American National thread system. The four basic thread series are:

—*Coarse-thread series,* with threads designated as UNC in the Unified system and NC (National Coarse) in the American National system;
—*Fine-thread series,* with threads designated UNF and NF;
—*Extra-fine-thread series,* UNEF and NEF;
—*Constant-pitch series,* 8 UN, 12 UN, and 16 UN for the Unified system and 8 N, 12 N, and 16 N for the American National system.

There are a number of pitch series in the constant-pitch series. There is the 8-pitch, 12-pitch, and 16-pitch series, and others. *Constant-pitch* means there are the same number of threads per inch for all diameters that are included in the series. For example, the 12 N series always has 12 threads per inch regardless of the outside thread diameter. The constant-pitch series is used when the other three thread series fail to meet specific requirements.

There are also designations for special conditions that require a nonstandard or special thread series. Some drawings show the symbol UNS, which indicates that the threads are Unified Special, or NS, which indicates National Special threads.

**TABLE 13–2** Selected ISO Metric Thread Fine Series (2–24mm)

| *Outside Diameter (mm)* | *Pitch* | *Tap Drill Diameter* |
|---|---|---|
| 8 | 1.0 | 7.0 |
| 10 | 1.25 | 8.8 |
| 12 | 1.25 | 10.8 |
| 14 | 1.5 | 12.5 |
| 16 | 1.5 | 14.5 |
| 18 | 1.5 | 16.5 |
| 20 | 1.5 | 18.5 |
| 22 | 1.5 | 20.5 |
| 24 | 2.0 | 22.0 |

## ISO METRIC THREADS

The ISO metric threads for all general threading and assembling purposes are identified with the *ISO Metric Coarse series*. The *ISO Metric Fine series* is employed in fine precision work. Table 13–1 shows twelve common ISO metric thread sizes ranging from 2–24mm. These sizes cover about the same range as the fractional inch sizes in the National Coarse series up to 1" outside diameter. There are additional standard sizes in the ISO Metric Coarse series beyond the 2–24mm range. The nine common thread sizes in the ISO Metric Fine series cover an equivalent range of fractional inch sizes in the National Fine series up to 1". Table 13–2 gives tap drill diameters equal to outside thread diameters minus pitch.

In Table 13–1, for example, the coarse series shows that an ISO metric threaded part with an 8mm outside diameter has a pitch of 1.25mm. The information would appear on an industrial print or drawing as M8-1.25 for the tapped hole it represents. The tap drill diameter is 8mm – 1.25mm, or 6.75mm, which is rounded off to 6.8mm for the tap drill size.

More complete tables cover the whole range of sizes and series. These tables are contained in trade handbooks, Standards Association papers, manufacturers' technical manuals, and other printed manuals.

## CUTTING INTERNAL THREADS WITH HAND TAPS

The process of cutting internal threads is referred to as *tapping*. Internal threads may be formed with a cutting tool called a *tap*. Taps are used to meet three general tapping requirements. Sections of taps showing these requirements appear in Figure 13–5. Some holes are

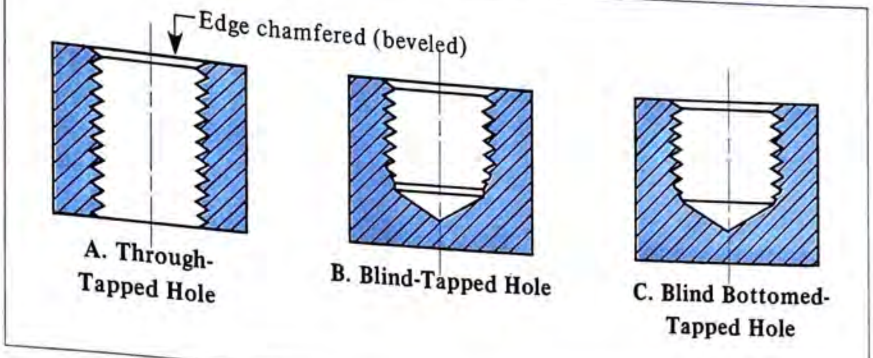



FIGURE 13–5 General Tapping Requirements

tapped *through* a workpiece (Figure 13–5A). Other holes are tapped part of the way through and are called *blind holes* (Figure 13–5B). Some blind holes are *bottomed* with a thread (Figure 13–5C).

## Features of Hand Taps

A tap is a specially shaped, accurately threaded piece of tool steel or high-speed steel. After a tap has been machined almost to size and form, its threads are *relieved* (reduced in size) to produce cutting edges. The tap is then hardened and tempered. A fine tap is ground to size and shape.

The general features of a hand tap are represented in Figure 13–6. A number of *flutes* (grooves) are milled into the body for the length of the threaded portion. These flutes help to form the cutting edges. The flutes also provide channels so that chips can move out of the workpiece along the flutes during the cutting process. Regular taps have straight flutes. Some taps are *spiral fluted* to produce a different cutting action in which the shearing that takes place and the spiral shape push the chips ahead of the tap.

The *shank* on some taps is smaller in diameter than the tap drill size. This difference in diameter permits the last teeth on the tap to be employed in cutting a thread. Also, the tap may be turned until it completely moves through the workpiece. Besides being smaller in diameter, the shank end is square. The square shape provides a good bearing surface for a tap wrench and for turning

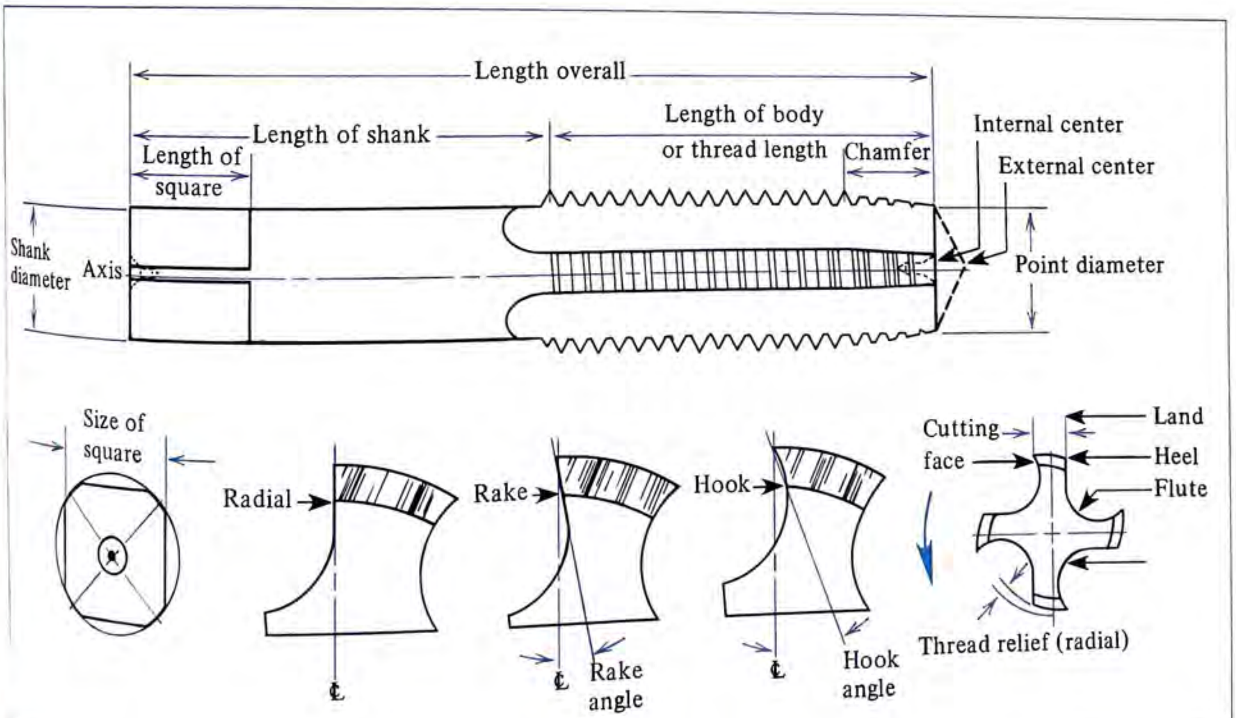



FIGURE 13–6 Principal Features of a Hand Tap

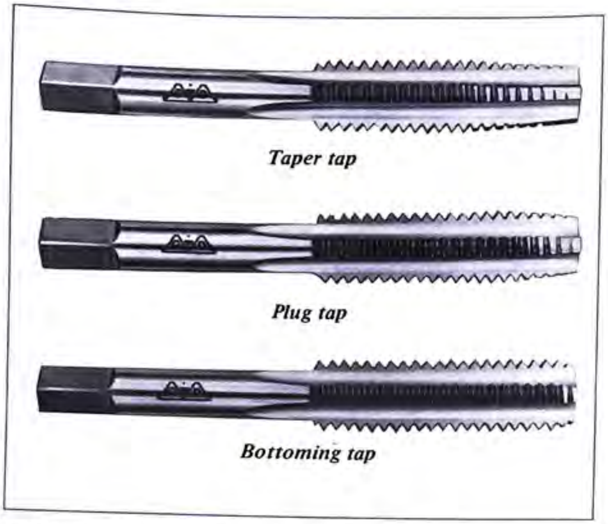



**FIGURE 13–7** A Standard Set of Hand Taps

the tap. Sometimes there is a *center hole* on the shank end. The center hole is used to align the tap at the line of measurement. Alignment is essential in starting the hand tap and in tapping on a machine.

## Tap Sets

***Standard Sets.*** Taps that are larger than 1/4″ usually come in standard size sets for each thread size and pitch. A set consists of three taps: a *taper* tap, *plug* tap, and *bottoming* tap (Figure 13–7).

The taper tap is sometimes called a *starting* tap. It may be used to start the hand tapping process, particularly when threading a blind hole, or to tap a hole that is drilled completely through a part. The taper tap has the first eight to ten threads ground at an angle (backed off). The taper begins with the tap drill diameter at the point end. It extends until the full outside diameter is reached. These angled threads start the tap and do the rough cutting. Because the taper tap has a greater number of angled teeth engaged in cutting the thread than plug and bottoming taps, less force is required. Also, the taper tap is easier to align with the line of measurement, and there is less likelihood of breakage.

The plug tap has the first three to five threads tapered. The plug tap is usually the second tap that is used for tapping threads (the taper tap being the first). It may be used for tapping through a part or for tapping a given distance. Certain blind-hole tapping is done with a plug tap if the last few threads need not be cut to the total depth.

The bottoming tap is *backed off* (tapered) at the point end from one to one and one-half threads. This tap is the third tap that should be used when a hole is to be blind tapped and is to *bottom* (cut a full thread) at the end of the tap drill hole. The bottoming tap should be used after the plug tap. Extra care must be taken near the end of the thread to see that the tap is not forced (jammed) against the bottom of the hole. Since so much force is applied on the first few teeth that do most of the cutting, it is especially important to use a complete set of taps.

***Machine-Screw Taps.*** Tap sizes that are smaller than 1/4″ are designated by whole numbers rather than by fractions. For example, a designation of 10–32 means that the outside diameter (OD) of a machine-screw tap is equal to the number of the tap (#10) times 0.013 plus 0.060″. For the 10–32 tap the outside diameter, calculated by using the formula, equals $(10 \times 0.013) + 0.060''$, or 0.190″. The "32" refers to the number of threads per inch. Thus, a 10–32 tap is one that has an outside diameter of 0.190″ and cuts 32 threads per inch.

On smaller size taps the amount of material to be removed in cutting the thread form is limited. The use of two or three taps in a set is therefore not required.

***Serial Set Taps.*** There are times when deep threads must be cut by hand in tough metals. Taps that cut deep threads have a different design than standard taps. These taps are known as *serial* taps. A serial tap set is shown in Figure 13–8. The outward appearances of these taps are similar to the taper, plug, and bottoming taps. They differ in the amount of material each tap cuts away.

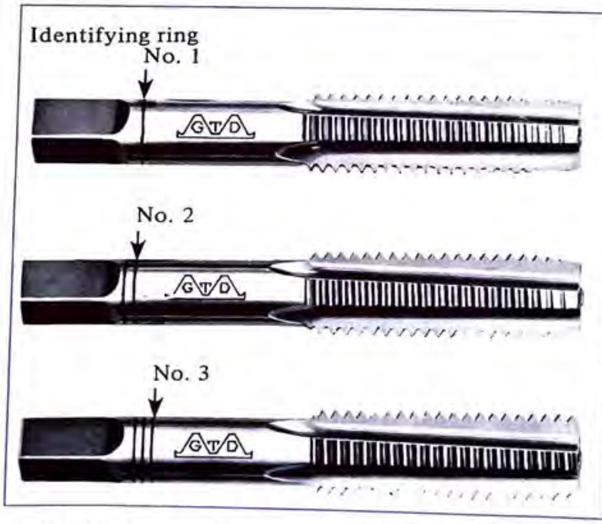



**FIGURE 13–8** A Serial Set of Hand Taps

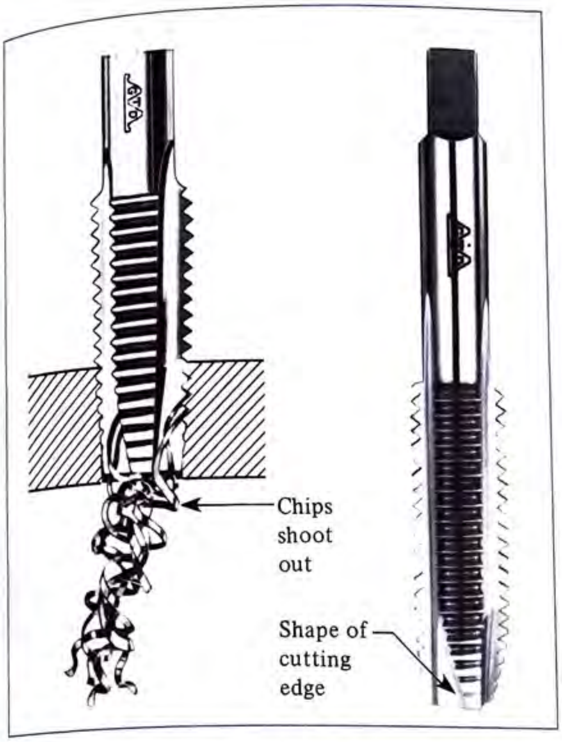



FIGURE 13–9 Cutting Action of a Plug Gun Tap

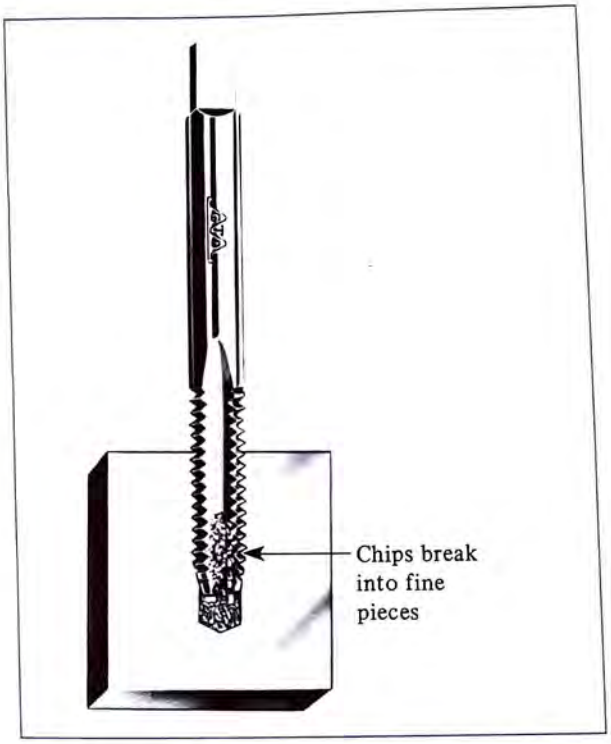



FIGURE 13–10 Cutting Action of a Bottoming Gun Tap

The first two taps cut to a portion of the required tooth depth. These taps are known as #1 and #2. They are identified by the number of grooves cut around the shank at the head end, one groove for #1 and two grooves for #2. The #1 tap cuts a shallow thread. The #2 tap cuts the thread deeper. The #3 tap is the final sizing tap. It cuts to the required depth to correctly form the teeth.

Serial taps must be used in sets. A combination of these taps reduces the amount of force exerted on any one tap and helps avoid tap breakage.

## Other Types of Hand and Machine Taps

***Gun Taps.*** Gun taps derive their name from the action caused by the shape at the point end of the tap. The cutting point is cut at an angle. The design of the point causes chips to shoot out ahead of the tap. The cutting action is shown in Figure 13–9. Gun taps are applied primarily in tapping through holes in stringy metals whose chips tend to bunch up and lodge in straight-fluted taps. With these metals, tapping requires that a greater force be exerted on a tap. This force increases the probability of tap breakage.

Gun taps are production taps. To withstand the greater forces required in machine tapping, there are fewer flutes on gun taps and the flutes are cut to a shallower depth than standard taps.

Gun taps are furnished in three general forms. Because each form performs a function that is different from the function of a standard tap, the names vary from the names of standard taps. The three forms of gun taps are the *plug gun, bottoming gun,* and *gun flute only* tap.

The plug gun tap is used for through tapping where holes are open and chips may shoot out.

The bottoming gun tap is used for bottoming tapping operations. The point end and the flutes of the bottoming gun tap have a special design. The flutes are cut deeper than the flutes of a standard tap to accommodate the metals to be tapped and the machine method of tapping. The design of the point angle causes chips to break into fine pieces (Figure 13–10). The chips are then removed easily.

The gun flute only tap is used on soft and stringy metals for shallow through tapping. The design features of this tap appear in Figure 13–11. A large cross-sectional

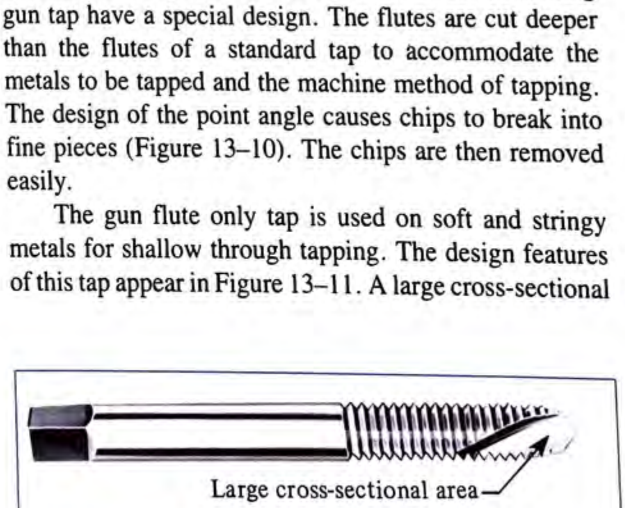



FIGURE 13–11 A Gun Flute Only Tap

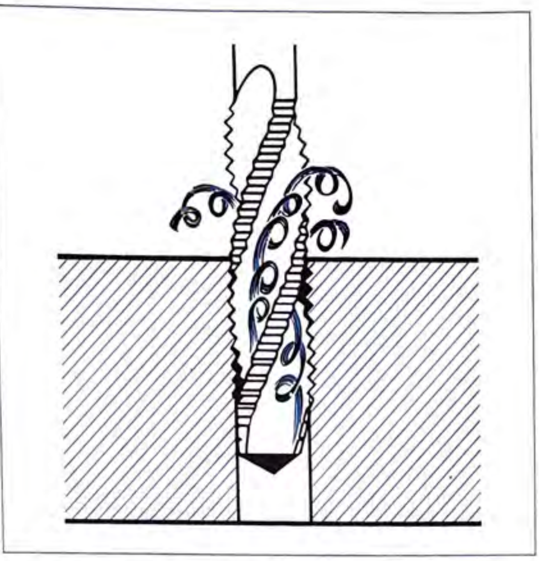


**FIGURE 13–12** Cutting Action of a Low-Angle Spiral-Fluted Tap

**FIGURE 13–13** A Standard Taper Pipe Tap (for NPT threads)

**FIGURE 13–14** A Straight Pipe Tap (for NPS threads)

area gives added strength and permits gun flute only taps to be powered with higher-force turning devices than regular machine taps.

***Spiral-Fluted Taps.*** *Low-angle spiral-fluted* taps are especially adapted for tapping soft and stringy metals. Such metals include copper, aluminum, die-cast metals, magnesium, brass, and others. Instead of straight flutes, these taps have spirals. The spiral flutes provide a pathway along which chips may travel out of a workpiece. The cutting action of a low-angle spiral-fluted tap is shown in Figure 13–12.

*High-angle spiral-fluted* taps are excellent for tapping (1) tough alloy steels, (2) threads that are interrupted and then continue in a part, and (3) blind holes.

***Pipe Taps.*** Three common forms of pipe taps are used to cut American National Form Pipe Threads. These threads include (1) standard taper pipe threads, (2) straight pipe threads, and (3) dryseal pipe threads. The processes of producing pipe threads are similar to processes used for tapping any other American National Form threads. The *taper pipe* tap forms NPT (National Pipe Taper) threads (Figure 13–13). The *straight pipe* tap cuts NPS (National Pipe Straight) threads (Figure 13–14). The *dryseal pipe* tap produces American National standard dryseal pipe threads.

Standard taper pipe threads and straight pipe threads are the same shape as the American National Form. Their thread angle is 60°. Their crests and roots are flattened. Their differences lie in diameter designation and pitch. Pipe threads taper 3/4″ per foot.

Parts cut with tapered pipe threads may be drawn together to produce a rigid joint. When a pipe compound seal is used on the threads, the line is made gas or liquid leakproof.

Straight pipe threads are used in couplings, low-pressure systems, and other piping applications where there is very limited vibration.

Dryseal pipe threads are applied in systems requiring pressure-tight seals. These seals are supplied by making the flats of the crests the same size or slightly smaller than the flats on the roots of the adjoining (mating) thread. Figure 13–15A shows the initial contact between crests and roots as a result of hand turning. A pressure-tight seal produced when parts are further tightened by wrench is illustrated in Figure 13–15B.

## FLUTE DEPTH AND TAP STRENGTH

While referred to as hand taps, a number of taps also are used for machine tapping. The difference in some cases is in the material from which a tap is made. Hand taps are usually manufactured from high-carbon tool steel; machine taps, from high-speed steel.

Tap sizes that are 1/2″ or larger normally have four flutes. Sizes smaller than 1/2″ may have two, three, or four flutes. For example, machine-screw taps usually have three flutes. The three flutes are cut deeper than flutes of large tap sizes and provide extra space for chips in blind-hole tapping or in tapping deep holes where chips are stringy.

A two-fluted tap has even more flute space for chips in proportion to the amount of material to be removed than a three-fluted tap has. By cutting the flutes deeper, the tooth material between the grooved areas of the tap is reduced. Thus, the strength of the tap to resist shearing forces that may cause the tap to fracture and break is also reduced.

In summary, a four-fluted tap is stronger than a deeper cut three-fluted tap; a three-fluted tap has greater strength than a deeper cut two-fluted tap. Where the flutes (grooves) are cut shallower, as in the case of gun taps, the tap strength is increased.

## TAP DRILL SIZES AND TABLES

A *tap drill* refers to a drill of a specific size. A tap drill produces a hole in which threads may be cut to a particular thread depth.

### Tap Drill Sizes

The *tap drill size* may vary from the root diameter required to cut a theoretical 100% full thread to a larger diameter. The larger diameter leaves only enough material to cut a fraction of a full-depth thread. According to laboratory tests, a 50% depth thread has greater holding power than the strength of the bolt. In other words, the bolt shears before the threads of the tapped hole strip.

The material in a part, the length of thread engagement, and the application of the thread itself are considerations for establishing the percent of the full-depth thread that is required. Finer threads for precision instruments may be cut close to their full depth. By contrast, bolts, nuts, and deep-tapped holes in the NC, UNC, or ISO Metric coarse series may require a smaller percentage of the full-depth thread. The possibility of tap breakage is reduced when holes are threaded to a fraction of the full depth.

The accepted practice in shops is to use a tap drill that provides approximately 75% of the full thread. The tap drill size may be computed by formula. An easier and more accurate and practical way to find the correct tap drill size is to use a handbook or a tool manufacturer's handy reference table.

When the tap drill size is to be computed, values may be substituted in the following formula:

$$\begin{matrix}\text{tap drill size} \\ \text{(75\% of} \\ \text{total depth)}\end{matrix} = \begin{matrix}\text{outside} \\ \text{diameter}\end{matrix} - \left(0.75 \times \frac{1.299}{\text{number of threads per inch}}\right)$$

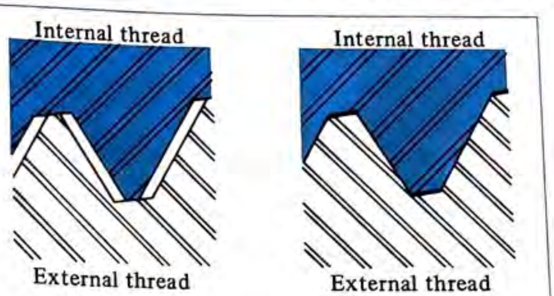



**FIGURE 13–15** How Dryseal Pipe Threads Produce a Pressure-Tight Seal

If a thread depth other than 75% is specified, substitute the required percent in place of 0.75. The nearest standard size drill is selected as the tap drill.

### Tap Drill Tables

The Appendix contains a series of thread tables. One table is titled *Hole Sizes for Various Percents of Thread Height and Length of Engagement*. Two other tables relate to various thread dimensions in the UNC/NC and UNF/NF series.

Parts of two simplified tables with just a few thread sizes are used here to illustrate tap drill size tables. The sizes all relate to a thread depth of approximately 75%. Refer first to Table 13–3, which covers UNC/NC threads. Note, as an example, that a 1/2–13 UNC/NC thread requires a 27/64″ tap drill to produce a 75% thread. By

**TABLE 13–3** Tap Drill Sizes (75% thread) UNC/NC Series

| *Thread Size and Threads per Inch* | *Major Outside Diameter (Inches)* | *Tap Drill Size* | *Decimal Equivalent of Tap Drill* |
|---|---|---|---|
| 1/4–20 | 0.2500 | #7 | 0.2010 |
| 5/16–18 | 0.3125 | F | 0.2570 |
| 3/8–16 | 0.3750 | 5/16 | 0.3125 |
| 7/16–14 | 0.4375 | U | 0.3680 |
| 1/2–13 | 0.5000 | 27/64 | 0.4219 |
| 9/16–12 | 0.5625 | 31/64 | 0.4844 |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |

**TABLE 13–4** Tap Drill Sizes (75% thread) UNF/NF Series

| *Thread Size and Threads per Inch* | *Major Outside Diameter (Inches)* | *Tap Drill Size* | *Decimal Equivalent of Tap Drill* |
|---|---|---|---|
| 5–44 | 0.1250 | #37 | 0.1040 |
| 6–40 | 0.1380 | #33 | 0.1130 |
| 8–36 | 0.1640 | #29 | 0.1360 |
| 10–32 | 0.1900 | #21 | 0.1590 |
| 12–28 | 0.2160 | #14 | 0.1820 |
| 1/4–28 | 0.2500 | #3 | 0.2130 |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |

contrast, Table 13–4 shows that a 10–32 UNF/NF thread requires a #21 tap drill (0.159″) for a 75% depth thread.

## TAP WRENCHES

Taps are turned by specially designed *tap wrenches*. Two general forms of wrenches are the *T-handle* and the *straight-handle* (Figure 13–16). Both of these wrenches have adjustable jaws that permit the use of a single tap wrench handle to accommodate a number of taps with different sizes of square heads. However, the range of tap sizes is so great that tap wrenches are made in a number of sizes.

The size of the square head of a tap is proportional to the tap size. Care must be taken to select the appropriate size of tap wrench. Many taps are broken because excessive force is exerted through the leverage of a wrench that is too large. While designed principally for use as tap wrenches, these wrenches are also used with other square-shanked cutting tools for hand turning operations.

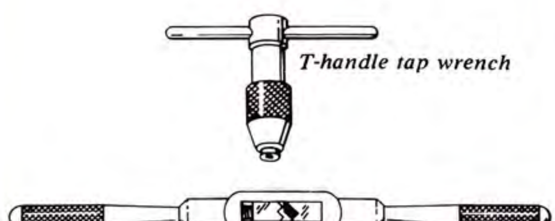



**FIGURE 13–16** General Forms of Tap Wrenches

### How to Tap Internal Threads by Hand

**Selecting the Tap and Tap Wrench**

STEP 1 Examine the thread specifications on the work order, print, or shop sketch.

STEP 2 Determine the most practical tap to use (that is available). The correct tap depends on the material, length of thread, and percent of thread depth required. Select an appropriate size and type of tap wrench.

STEP 3 Refer to a table of tap drill sizes for the thread size and form series. Determine the tap drill size that meets the job specifications.

*Note:* Shop prints normally carry a notation on the size of drill and depth, particularly for blind holes.

STEP 4 Check the drilled hole for correct tap drill size and depth. Remove all chips. If possible, the drilled hole should be countersunk slightly. Countersinking helps in starting a thread and prevents throwing up a burr.

**Starting the Tap**

STEP 1 Mount the workpiece securely in a vise. Check the hole to see that it is in a vertical position.

STEP 2 Start with a taper tap. Tighten the shank end in the wrench jaws. Grasp the tap and tap wrench in one hand. Place the tap in the tap hole. Guide the tap with the other hand so that it is vertical. (Figure 13–17 shows the correct position of a tap at the start.)

STEP 3 Apply a slightly downward force while turning the tap clockwise at the same time. Continue to turn with one hand. Apply a constant force for two or three turns. This force should cause the tap teeth to start to form partial threads.

**Checking for Squareness**

STEP 1 Remove the tap wrench carefully. Clean the work surface and check for burrs at the beginning of the thread. Check the tap for squareness (Figure 13–18). Bring the blade of a square against the tap shank in two positions at 90° to each other.

*Note:* If the tap is not square, back it off by reversing the direction. Restart the tap by turning it clockwise. Apply a limited force in the direction from which the tap leans.

*Note:* Care and judgment are needed. A tap is brittle. Any sharp jarring or excess force at an angle may cause a tap to snap and break.

STEP 2 Turn the tap two or three turns. Repeat the checking and adjusting steps until the tap is square with the workpiece.

STEP 3 Apply a small quantity of an appropriate lubricant to the cutting edges of the tap.

*Note:* Use turpentine or a mineral spirit for very hard materials. Steel, bronze, and wrought iron require a lard oil. Soft metals and cast iron may be hand tapped without a lubricant.

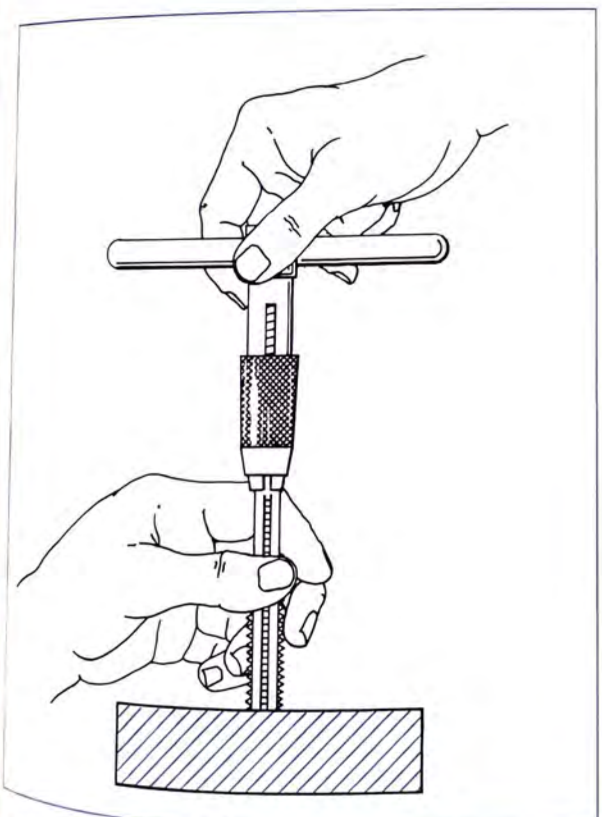


**FIGURE 13–17** Positioning a Tap at the Start

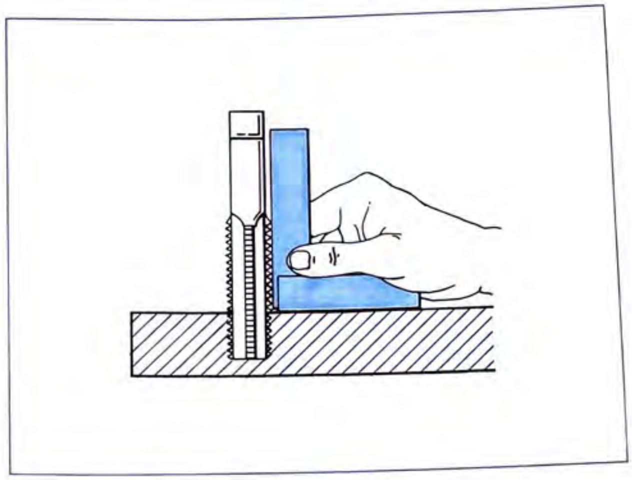


**FIGURE 13–18** Checking a Tap for Squareness

**Tapping a Through Hole**

STEP 1 Turn the tap with both hands on the tap wrench handles. As the tap takes hold, the downward force may be released.

*Note:* The two handle ends of small tap wrenches should be held and turned with a steady, gentle, even force (Figure 13–19). Larger straight-handle tap wrenches and taps are turned by grasping one end of the handle with one hand and the other end with the other hand. (The correct position of the hands is shown in Figure 13–20.)

**FIGURE 13–19** Tapping with a T-Handle Tap Wrench

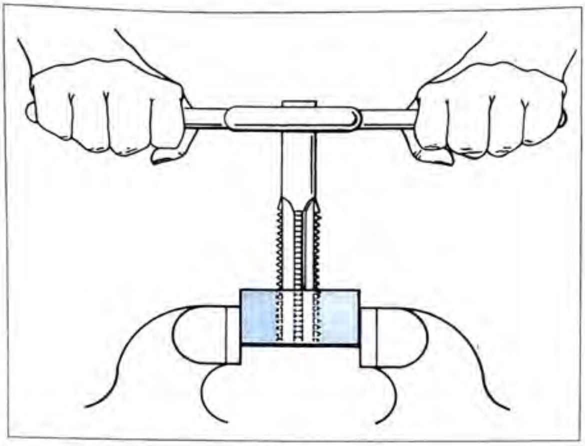


**FIGURE 13–20** Tapping with a Straight-Handle Tap Wrench

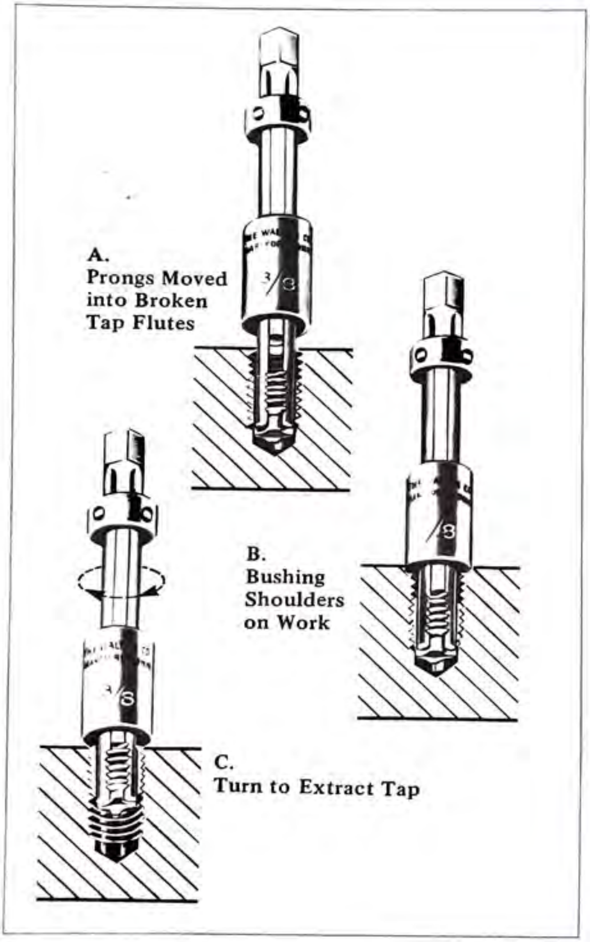



**FIGURE 13–21** Application of a Tap Extractor

STEP 2 Back off the tap after each series of two or three turns. Backing off is done by reversing the direction of the tap. The reversing action causes the chips to break. They then can move through the flutes and out of the work. Backing off also prevents tap breakage.

STEP 3 Continue to turn the tap, repeating the steps for cutting, lubricating, and backing off. The starting taper tap may either be moved through the workpiece or removed by reversing the direction.

*Note:* It is good practice to follow the taper tap with a plug tap. The plug tap then serves as a finishing or sizing tap.

### Tapping a Blind Hole

STEP 1 Determine in advance how much of the tap should be above the work surface when the work is tapped to the required depth. Start to tap.

*Note:* A taper tap may be used to start the tapping of deep blind holes. A plug tap is used for tapping shallow blind holes.

STEP 2 Remove the tap and the chips in the blind hole.

*Caution:* Goggles must be worn during the chip-clearing process. The workpiece should be turned away from the operator and covered with a wiping cloth to prevent the chips from flying in the area.

STEP 3 Reposition the work in the vise. Continue to tap. Check the depth occasionally. A steel rule placed on the work surface and next to the tap body may be used to roughly check the depth.

*Note:* It may be necessary to remove the chips a second time from the blind hole.

STEP 4 Repeat the tapping steps with a bottoming tap if the threads must be bottomed.

*Note:* The first few teeth of the bottoming tap cut to the full thread depth. Bottoming requires considerable force. The tap must be turned slowly near the end of the hole and stopped as soon as the tap bottoms.

STEP 5 Remove the tap when the thread is bottomed. File away any burrs raised on the surface by tapping. If possible, take a countersink and turn it by hand in the tapped hole to remove any fine, rough edge at the top of the thread. Finally, thread the plug tap through the tapped hole to remove any remaining particles.

STEP 6 Clean the workpiece. Check the accuracy of the thread with a thread plug gage, the mating threaded part, or a bolt or screw.

## TAP EXTRACTORS

The name *tap extractor* indicates that the tool is used to extract parts of taps that have broken off in a hole (Figure 13–21). The extractor has prongs. These prongs fit into the flute spaces of a broken tap. The prongs are pushed down into the flutes. The steel bushing on the extractor is moved down as far as possible to the work. The bushing thus provides support for the prongs. The extractor is turned counterclockwise with a tap wrench to remove a broken right-hand tap. After the broken tap is removed, the tapped hole should be checked to see that no broken pieces remain in the hole.

### How to Extract a Broken Tap

STEP 1 Remove any fractured tap particles near the top surface with a pair of pliers.

*Caution:* Taps normally break into sharp fragments. These fragments should be removed only with other hand tools.

STEP 2 Select a tap extractor appropriate for the tap size. Slide the extractor prongs down into the tap flutes as far as possible (Figure 13–21A).

STEP 3 Move the steel bushing over the prongs and down to the work surface (Figure 13–21B).

STEP 4 Turn the extractor with a tap wrench in the direction opposite to the direction of the tapping process (Figure 13–21C).

STEP 5 Continue turning the extractor a few turns. Then reverse the turning to dislodge any chips. These chips may cause the tap to bind. Repeat the process until the tap is removed.

STEP 6 Clean the part. Recheck the hole for remaining chips and broken tap particles. Check to see that the tap drill size is correct.

STEP 7 Retap the hole.

### Safe Practices with Threading Tools and Processes

—Check the tap drill and hole size before the tapping process is started. Undersized tap drills require excessive force.

—Use a standard taper tap, wherever practical, as a starting tap.

—Use a bottoming tap as a finishing tap for blind-tapped holes.

—Reverse a standard hand tap during the cutting process. A reversing action breaks the chips, makes it easier to move them out of the tapped hole, and reduces the force exerted on the tap.

—Select a size and type of tap wrench that is in proportion to the tap size and related to the nature of the tapping process. Excessive force applied by using oversized tap wrenches is a common cause of tap breakage.

—Exercise care with bottoming taps, particularly in forming the last few threads before bottoming. Avoid excessive force or jamming the point of the tap against the bottom edge of the drilled hole.

—Back out a tap that is started incorrectly. Restart it in a vertical position, square with the work surface. Any uneven force applied to one side of a tap handle may be great enough to break the tap.

—Use caution when using an air blast. Chips should only be blown from a workpiece when (1) each operator in a work area uses an eye protection device and (2) the workpiece is shielded to prevent particles from flying within a work area.

—Handle broken taps carefully. Taps fracture into sharp, jagged pieces. Workpieces with parts of broken taps should be placed so that no workers brush up against them. Use only a hand tool, such as a pair of pliers, to grasp or try to move a broken tap.

—Chamfer the ends of a tapped hole with a countersink. A triangular scraper may also be used to remove any burrs produced by tapping.

—Select cutting fluids (lubricants) appropriate for the material being tapped. The cutting fluids reduce the force required for tapping, help the tap cut easier, and produce a smoother finished thread.

## SCREW THREAD AND HAND TAPPING TERMS

**Internal or external screw thread** A helical ridge of uniform section. A ridge formed in a straight or tapered cylindrical hole (internal) or outside diameter.

**USS, SAE** Early coarse and fine thread series standards. Beginning standards that are presently incorporated in the American National Form Coarse series (NC) and Fine series (NF).

**Unified thread form** Thread form standards adopted by Great Britain, Canada, and the United States. Standards that ensure interchangeability of threaded parts conforming to the national standards of these countries. A 60° included angle thread form with crest and rounded root. A thread form that incorporates features of the British Standard Whitworth and the American National Form.

**National Coarse and National Fine** Two basic thread series built upon the American National Form. (Coarse series (NC) threads are used on parts and instruments requiring finer, more precise threads.)

**International (ISO) metric thread system** A metric thread system accepted as an international standard. A thread form having a 60° thread angle. (The crests and roots are flattened at 1/8th of the depth. A rounded root is recommended. Drawings are dimensioned with metric thread specifications.)

**Pitch-diameter series** A thread system proposed by the Industrial Fasteners Institute. (The system is intended to reduce and replace current Unified and ISO Metric pitch-diameter combinations.)

**Constant-pitch series** A threaded series in which the pitch is the same for all diameters that are included in the series—for example, 8 pitch, 24 pitch, 32 pitch.

**ISO metric thread designation** Specifications of a metric thread giving the outside diameter and pitch in millimeters—for example, M20-2.5 means an outside diameter of 20mm and a pitch of 2.5mm.

**Flutes** Channels running parallel to a tap axis and cut below the thread depth. Grooves that form the teeth of a tap. Channels into which chips flow and are removed during the cutting process.

**Relieved** The reduction in size of the mass behind a shape. The removal of material behind a cutting edge. (The removal produces the cutting edge and permits a cutting tool to be turned with minimum resistance, drag or friction.)

**Bottoming** A common threading term used to indicate that as close to a full thread as possible must be produced at the bottom of a hole.

**Serial set taps** A set of three progressively larger taps (#1, #2, and #3). A set where the #3 tap conforms to the correct thread specifications. A set of three taps, each of which must be used in succession to produce a full thread form.

**Spiral-fluted taps** Specially designed taps for soft, stringy metals (low-angle) or tough alloy steels (high-angle).

**Tap drill** A standard drill corresponding in size to the diameter to which a hole must be drilled. (The tap drill permits cutting a thread to a specified depth.)

**Tap extractor** A pronged tool inserted in the flutes of a broken tap and turned to extract the tap.

## SUMMARY

The early forms of screw threads were layed out around a cylindrical surface. The threads were sawed and filed to shape.

Screw thread standards established in the United States by William Sellers represented modifications of the work of Whitworth and the British Standard system.

There are eight basic methods of producing threads: hand cutting, machine cutting with formed cutters, machine cutting with single-point and multiple-point cutting tools, milling, grinding, rolling and forming, and casting.

Screw threads serve four functions: to fasten parts, to change force, to produce motion, and to change motion.

Screw threads are classified as right- or left-hand, straight or tapered, and internal or external.

Five common thread series in the Unified and American National thread systems are:

—Coarse: UNC/NC

—Fine: UNF/NF

—Extra fine: UNEF/NEF

—Constant pitch: UN/N

—Special: UNS/NS

The American National thread form for the NC series evolved from the earlier Sellers Standard and the USS coarse-thread series. The NF series developed from the former SAE fine-thread series.

The Unified thread form has a 60° included angle. The thread has a flat crest (1/8 P) and root (1/6 P), which is preferably rounded.

The ISO metric thread system has a 60° included angle with a flat crest and root. Crest and root are each equal to 1/8 P. A rounded root is preferred. Dimensions are in metric units of measurement.

ISO metric coarse and fine series threads are identified on drawings by the letter M followed by the outside diameter and pitch size—for example, M12-1.75.

Standard hand tap sets include taper (for starting), plug (for through and deep-hole tapping), and bottoming taps.

A cutting fluid, appropriate for the material being tapped, helps the cutting action, improves the quality of the finished threads, and reduces the force required for tapping.

The tap drill produces a hole size with enough remaining material to form a thread of a specified depth.

Machine-screw taps under 1/4" are designated by number. Usually a single tap is used to cut the thread to a required percent depth.

Serial set taps are designated for cutting tough materials. Taps #1, #2, and #3 each cut a portion of the full thread depth. The #3 tap is the final finishing (sizing) tap.

The plug gun, bottoming gun, and gun flute only taps are production taps. These taps are used for stringy metals whose chips adhere to straight-fluted taps.

The low-angle spiral-fluted tap is designed for tapping soft metals. The high-angle spiral-fluted tap is for tough alloy steels and blind holes.

Straight (NPS), standard taper (NPT), and American National dryseal are three common forms of pipe threads.

There are usually fewer flutes (two and three) on small-sized taps. These flutes are cut deeper for greater chip clearance. These taps may be sheared and fractured easily.

Tap drill tables provide tap drill sizes based on length of thread, nature of material, and percent of full depth required. The formula for computing tap drill size for the National Form is:

$$\text{outside diameter} - \left( \frac{1.299}{\text{number threads per inch}} \times \%\ \text{thread depth required} \right)$$

A tap wrench should be selected in terms of the tap size and the location of the tapped hole.

Taps are brittle because of their construction and hardness. Extra care must be taken to see that the tap drill size is correct, the tap is started squarely, the workpiece is secured so that it will not move, a proper cutting fluid is used, the chips are broken regularly and are removed, and no undue force is applied on the tap.

## UNIT 13 REVIEW AND SELF-TEST

1. Describe the significant design changes of the early Sellers Standard for coarse screw threads.
2. Tell why it was necessary to adopt the SAE screw thread system in 1911.
3. State what compromises were made in the 55° British Whitworth thread form and the USS 60° thread form to standardize these forms into the Unified Screw Thread System.
4. Identify how the Industrial Fasteners Institute (IFI) proposes to reduce and replace the 125 Unified and ISO Metric pitch-diameter combinations for the coarse- and fine-thread series.
5. List four basic hand and machine (lathe cutting) methods of producing threads.
6. Differentiate between the pitch to diameter relationship of threads in the UNC series and the constant-pitch series (UN) for the Unified system.
7. Show how information about ISO metric threads with a 25mm outside diameter and a pitch of 4mm is represented on an industrial drawing.
8. Identify when each of the following taps is used: (a) taper, (b) plug, and (c) bottoming.
9. Tell when (a) low-angle spiral-fluted and (b) high-angle spiral-fluted taps are used.
10. Give one design feature of an American National standard dryseal pipe thread.
11. State why general-purpose threading to 75% of full depth is an accepted practice.
12. Explain how part of a tap that breaks in a hole may be removed safely.
13. List four safety practices to follow to avoid personal injury or tap breakage when threading.

# UNIT 14

# Drawings, Dies, and Hand Processes of External Threading

Historical and basic technical information about standards for thread forms and thread series, hand cutting tools, and tapping processes were covered for internal threads in Unit 13. This unit provides additional details that relate principally to external threads. Techniques are described for representing and specifying screw threads on shop drawings, prints, and sketches.

Today, it is still necessary and practical to cut threads by hand. While hand-cut threads may not be as precise as threads produced by machining processes, hand-cut threads do meet general requirements. The tools and processes used in bench work for cutting external threads and for measuring pitch are also described in this unit. More advanced technology and processes are covered in later units that deal with different forms and precision methods of cutting internal and external threads.

## SCREW THREAD SPECIFICATIONS AND DRAWING REPRESENTATION

### Drawings of Screw Threads

The designer's concept of an exact part is communicated to the craftsperson through the medium of a drawing. The craftsperson must be able to accurately interpret design features, dimensions, and the relationship of one part with another part. Each line, view, dimension, and note on a drawing has a particular meaning for the worker.

To review, threads may be external or internal. A thread may extend entirely through or over a given length. The thread may also be bottomed at the depth of a drilled hole, or it may go only a specified distance. Similarly, an external thread may be cut to a shoulder or threaded part way.

All screw thread specifications are usually shown graphically (represented) on drawings and sketches in one of three ways:

—Pictorial representation,
—Schematic representation,
—Simplified representation.

Figure 14–1 illustrates how internal and external threads are represented with pictorial, schematic, and simplified techniques.

### Dimensioning Screw Threads on Drawings

To provide all essential screw thread details, a drawing must include full specifications for cutting and measuring threads. Technical information about thread sizes, depth or length, class of threads (fits), and surface finish appear near the representation of the threaded portion. Sometimes the thread length is specified by a dimension on the part. Other instructions may be stated as notes.

Dimensions for internal and external threads are added to the part drawing. Simplified drawings of threads with dimensioning codes and dimensions are provided in Figure 14–2. Each drawing includes a series of encircled numerals. The type of dimension represented by a particular numeral is explained by a code (Figure 14–2C). Specifications of an external thread are given on a drawing as shown in Figure 14–2A. Details of a blind threaded hole (internal thread) appear on a drawing as illustrated in Figure 14–2B.

## MEASURING SCREW THREAD PITCH

*Pitch* is the distance at the same point on a thread form between two successive teeth. Two simple screw thread measurement techniques may be used to establish the pitch of a particular threaded part. The first technique requires the use of a screw pitch gage; the second technique, a steel rule.

### Screw Pitch Gage Technique

A *screw pitch gage* has a series of thin blades (Figure 14–3). Each blade has a number of teeth. The teeth match the form and size of a particular pitch. Each blade is marked for easy reading.

Pitch is checked by selecting one gage blade. The

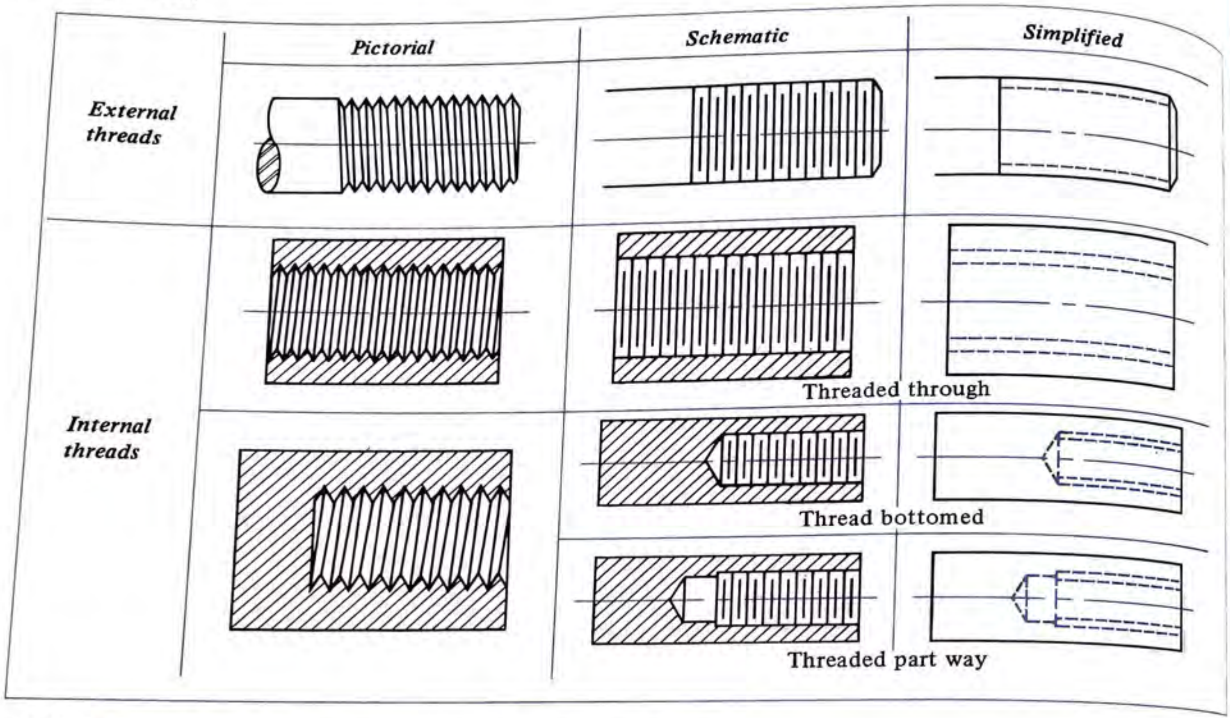



**FIGURE 14–1** Techniques for Representing Threads on a Drawing

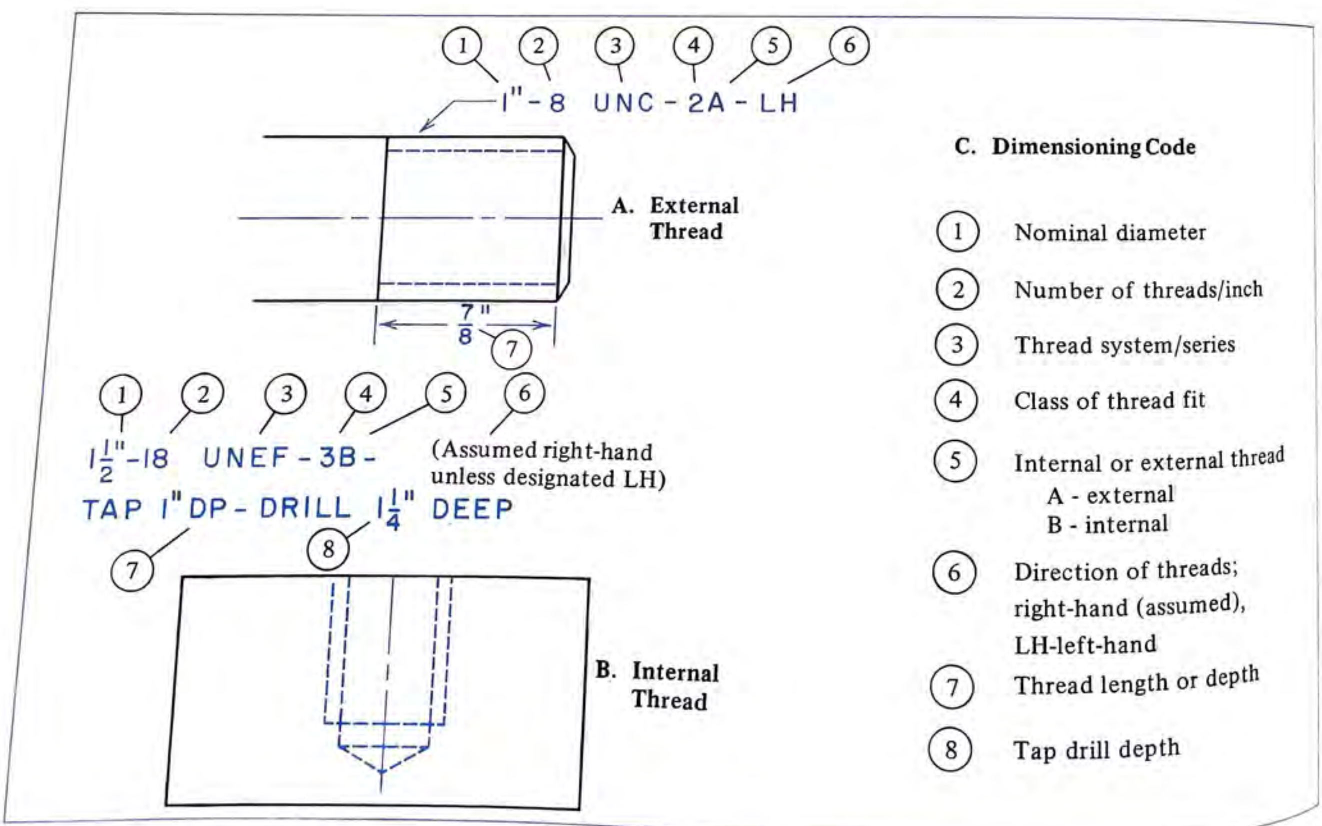



**FIGURE 14–2** Simplified Drawings of Threads, with Dimensions and Dimensioning Codes

blade teeth are placed in the threaded grooves of an actual part, as shown in Figure 14–3. The blade is sighted to see whether the teeth match the teeth profile of the workpiece. Different blades may need to be tried until a blade is found that conforms exactly to the workpiece teeth. The required pitch is thus established.

### Steel Rule Technique

Screw pitch may also be measured by placing a steel rule lengthwise on a threaded part (Figure 14–4). An inch graduation is usually placed on the crest of the last thread. The number of crests are counted to the next inch graduation on the rule. This number of crests (threads) represents the pitch. The technique is shown in Figure 14–4.

If the threaded portion is less than one inch, the number of threads in the given distance may be multiplied by the ratio that the fractional part bears to one inch. The pitch of a metric thread is expressed in millimeters. As stated earlier, pitch represents the distance from a specific point on one tooth to the corresponding point on the next tooth.

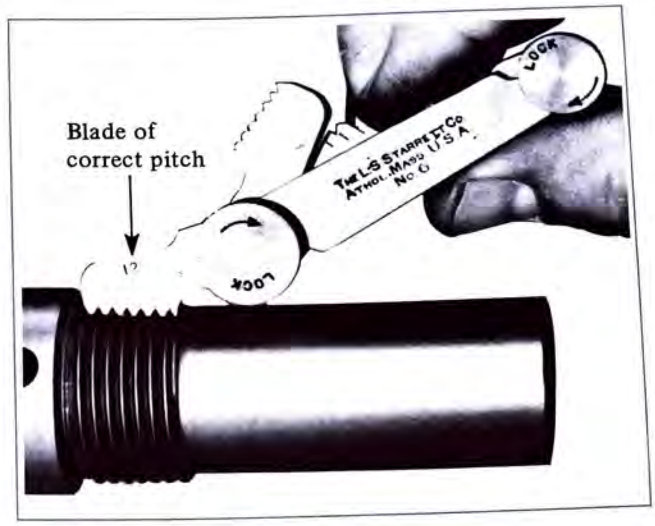



**FIGURE 14–3** A Screw Pitch Gage Used to Determine Thread Pitch

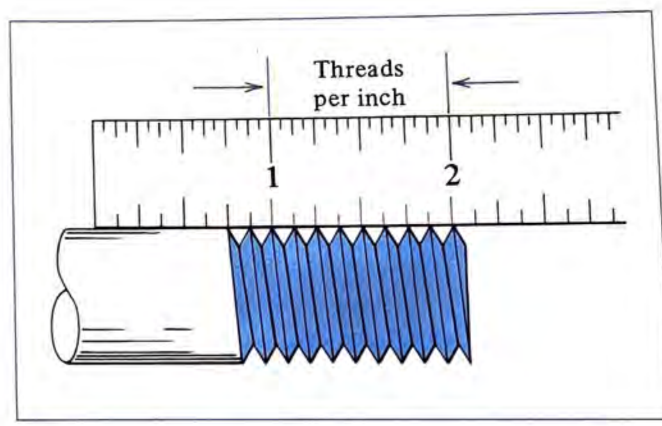



**FIGURE 14–4** Using a Steel Rule to Measure the Number of Threads Per Inch

## EXTERNAL THREAD CUTTING HAND TOOLS

External threads are hand cut with cutting tools known as *dies*. Dies are made in a variety of sizes, shapes, and types. Selection of dies depends on the thread form and size and the material to be cut. Dies are made of tool or high-speed steel and other alloys. Dies are hardened and tempered. Some dies are *solid* and have a fixed size. Other dies are *adjustable*.

Adjustable dies are split. Split dies permit adjustments to be made to produce a smaller or larger size thread. Sometimes the size adjustment is made with an *adjusting screw* in the die. At other times screws on a *die holder* provide for adjustments. Once adjusted, the position is secured. Or, an adjustable die may contain two *die halves* that are held in a cap. The three forms of hand threading dies are illustrated when they are each described in more detail.

### Solid Dies

The solid square- or hexagon-shaped die has a fixed size (Figure 14–5). Rarely used in the shop, it is applied principally to chase threads that have been poorly formed or have been damaged. Such threads require that a sizing die be run over them to remove any burrs or nicks or crossed threads. The damaged threads are reformed to permit a bolt or other threaded area to turn in a mating part. The hexagon shape may be turned with a socket, ratchet, or other adjustable wrench.

**FIGURE 14–5** A Solid Hexagon Die

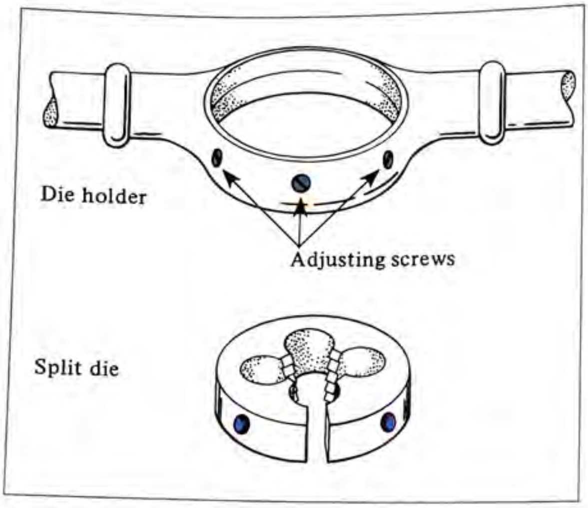



**FIGURE 14–6** Split Die Thread Size Controlled by Three Adjusting Screws

## Adjustable Split Dies

The adjustable split die is available in three common forms. The first form, shown in Figure 14–6, must be adjusted each time the die is changed in a *die holder*. In some cases the adjustment is made by turning the adjusting screws in the die holder (sometimes called a *die stock*). The split die is placed in the die holder and tried on a correctly sized threaded part. The screws are adjusted until there is a slight drag between the die and the threaded part. In other cases the die is adjusted by a cut-and-try method. The die is opened. A few full threads are cut. The workpiece is tried on the mating part. The die is adjusted until the correct size is reached. The die is then locked at the setting for this size.

The second form of adjustable split die has a screw within the die head (Figure 14–7). This *screw adjustment* opens or closes the die thread teeth. Thus a range of adjustments for cutting oversized or undersized threads is provided. The die is then mounted in a die holder. The die is held at the set position with the adjoining screws in the die holder.

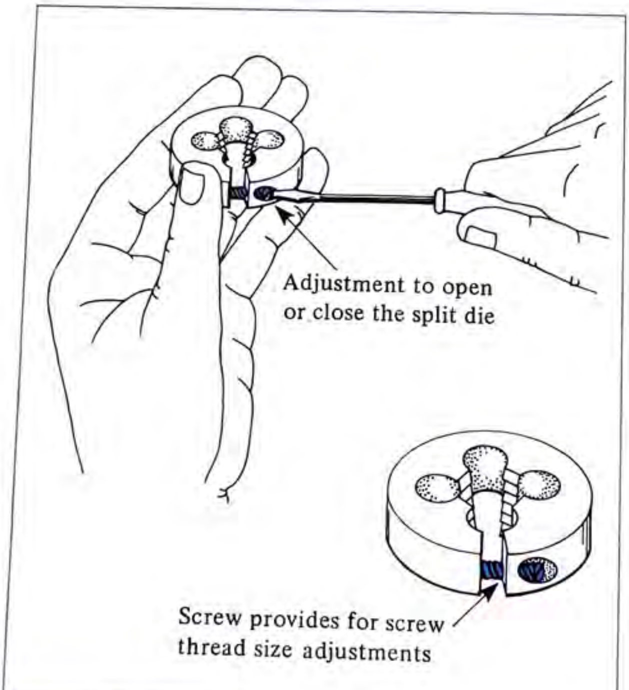



**FIGURE 14–7** A Split Threading Die with a Screw Adjustment

The third basic form of adjustable split die has three essential parts: a *cap*, a *guide*, and the *die halves* (which are the threading die). All the parts and their complete assembly are shown in Figure 14–8. The sides of the two die halves are cut at an angle. The die halves are held securely against the machined, tapered surfaces in the cap. The threads on the die halves are tapered at the front end. The taper permits easier starting and relieves excessive pressure on the first few cutting teeth. The cap has two adjusting screws. These screws move and position the die halves. The cap also has a lock screw recess by which the die is secured in the holder.

The guide serves two purposes:

—It forces the tapered sides of the die halves against similarly tapered sides in the cap. The force holds the two halves tightly in position so that the size cannot change.

—It pilots the die (halves) so that it is centered over a workpiece. Once the die halves are set to the required size, they are locked in position with the cap. The assembled die is then locked in the die holder.

The cutting teeth of the adjustable split die are formed by removing metal from portions of the thread form. Instead of flutes the area in back of the threaded section is removed to provide both a cutting edge and ample room for chips to clear the die. Since dies have more body than taps, they are considerably stronger and their chip channels may be cut deeper. The teeth are relieved in back of the cutting edge to make cutting possible and to avoid binding.

## Pipe Thread Dies

Pipe threads are tapered in order to make tight joints in air and liquid lines. Pipes are measured (sized) according to their inside diameter. Because of this inside measurement, pipe threads are larger in diameter than

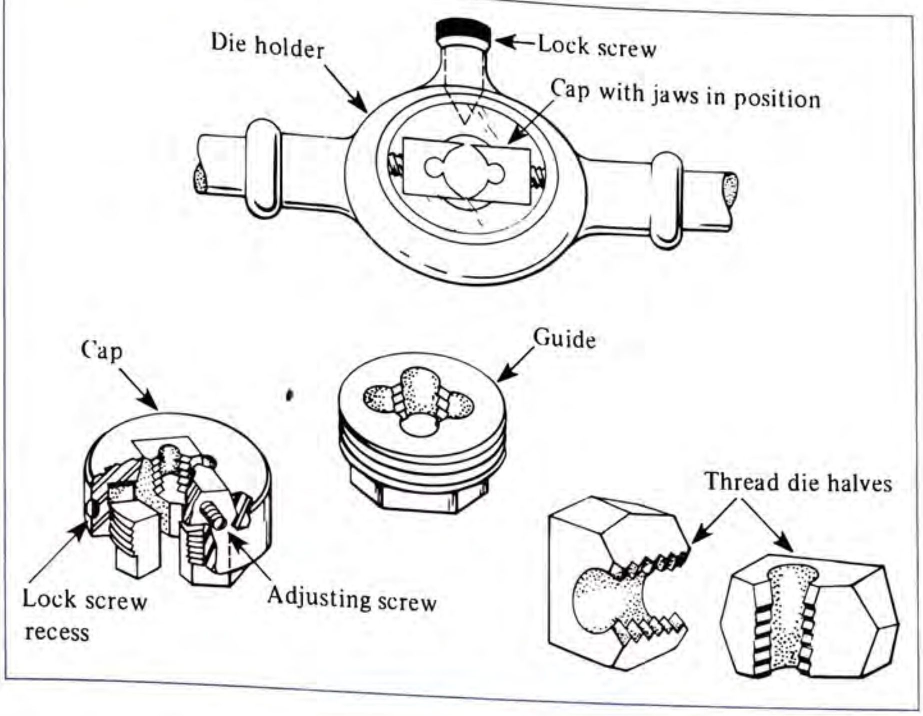



FIGURE 14–8 Features and Assembly of Die Halves, Guide, and Cap

regular screw threads. Pipe threading taps and dies are, therefore, larger for a specific diameter than regular taps and dies.

A 1/2″ standard taper pipe thread (NPT) requires a tap drill of 23/32″. This drill size permits a hole to be tapered with a thread taper of 3/4″ per foot. The actual outside diameter of the 1/2″ threaded pipe is 0.840″. Other common National taper pipe thread sizes are given in Table 14–1.

Dies for pipe threads may be solid or adjustable. The adjustable dies vary in thickness to correspond to the length of pipe thread that should be cut for a specific diameter. The die halves are held in an *adjustable stock* that serves as the die holder. There are indicating marks on both the die and the stock. When the die halves are aligned with these marks, the die is set to cut a standard pipe thread. The adjustable stock is provided with a positioning cap. This cap centers the work with the die halves.

Where single pipes are to be threaded by hand, a pipe plug or the mating part may be used as a gage. A pipe thread is cut to near its full depth, tried for size and fit, and then cut to the correct depth. Since sharp burrs are raised easily in pipe threading, care must be taken to remove them. Work surfaces must also be cleaned before parts are assembled.

Straight, taper, and dryseal pipe thread standards are found in handbooks. Taper pipe threads present an added problem of fitting parts carefully. Attention must be paid to start taps and dies squarely. An appropriate cutting lubricant must be used. Dies must be backed off to break the chips. Chips must be removed. Workpieces must be burred and cleaned.

## How to Cut Threads with a Hand Threading Die

### Selecting the Threading Die

STEP 1 Select an adjustable threading die that meets the job requirements for thread form and size. Select an appropriate type and size of die holder.

STEP 2 Check the outside diameter of the workpiece. Chamfer the sharp edge to a depth of one thread by turning or hand filing.

**TABLE 14–1** National Standard Taper (NPT) Pipe Threads

| *Nominal Pipe Size* | *Threads per Inch* | *Outside Diameter* | *Tap Drill Size* |
|---|---|---|---|
| 1/8 | 27 | 0.405 | 11/32 |
| 1/4 | 18 | 0.504 | 7/16 |
| 3/8 | 18 | 0.675 | 37/64 |
| 1/2 | 14 | 0.840 | 23/32 |
| 3/4 | 14 | 1.050 | 59/64 |
| 1 | 11-1/2 | 1.315 | 1-5/32 |
| 1-1/4 | 11-1/2 | 1.660 | 1-1/2 |
| 1-1/2 | 11-1/2 | 1.990 | 1-47/64 |
| 2 | 11-1/2 | 2.375 | 2-7/32 |

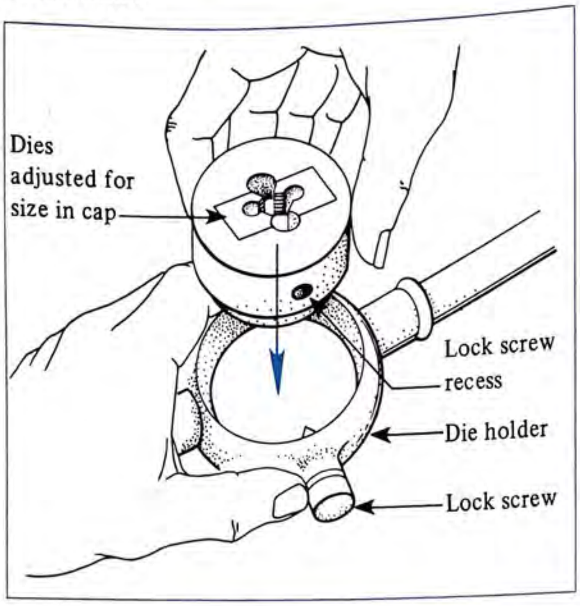



**FIGURE 14–9** Assembling a Two-Jaw Adjustable Threading Die

Chamfering to this depth is necessary to start the die squarely so that the thread will be cut straight.

### Adjusting the Threading Die

STEP 1 Test the adjustable threading die. Thread (turn) the mating part into the die by hand. Adjust the screw on a screw-adjusting die until a slight force is needed to turn the die.

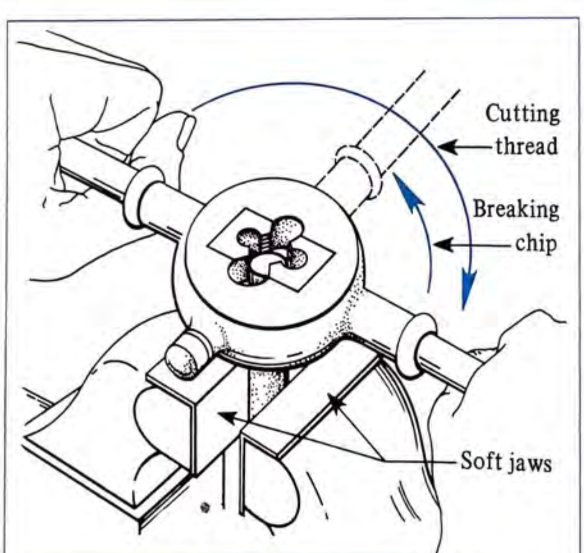



**FIGURE 14–10** Cutting a Right-Hand Thread and Reversing the Stroke to Break the Chips

*Note:* On some split dies the die may be positioned in a holder. The adjusting screws are then tightened to bring the die to size and to lock it in a fixed position (Figure 14–9).

*Note:* The lead side (tapered threads) of the die should be placed opposite the shoulder of the die stock.

STEP 2 Tighten the lock screw in the die holder.

### Starting the Thread

STEP 1 Mount the work securely in a vise. Use protecting soft jaws where required. Place the die on the work. The tapered starting cutting area is on the bottom facing the workpiece.

STEP 2 Apply a cutting lubricant to the work surface and the die cutting edges. Press down firmly. At the same time move the die on the top surface of the work.

STEP 3 Continue to apply a downward and circular force (Figure 14–10). Make two or three revolutions to start the first few threads. Back off the die. Check the threads for squareness and to see that they are started correctly.

STEP 4 Continue to turn the die until a few full threads are produced. Remove the die. Clean the part. Check the size against the mating part, a ring gage, or other measuring tool. If necessary, adjust the die jaws.

*Note:* A finer finished thread is produced when the die is opened as much as possible. The thread is cut to length. This step is then followed by readjusting the die and taking a fine cut to produce the required fit.

*Note:* As in tapping, the cutting direction should be reversed every few turns (Figure 14–10). A reverse cutting action breaks the chips and clears them away from the work surface and die.

*Note:* A cutting lubricant should be applied throughout the cutting process.

STEP 5 Thread to the required length. Remove the die. File off the burrs. Clean the threads. Retest the threaded part for size by turning it into the mating part. If required, readjust the die and take a finishing cut over the threaded part.

*Note:* When a thread is to be cut to a shoulder or close to a head, the die is turned 180° (inverted). The last few threads are cut with the die inverted.

*Caution:* Eye protection devices must be used and safety precautions must be followed while removing chips from dies.

## SCREW EXTRACTOR

Bolts, screws, studs, and other threaded parts may be sheared off, leaving a portion of the broken part in the tapped hole. This portion may be removed by using a tool called a *screw extractor*. This tool is a tapered metal spiral. A right-hand thread screw extractor is illustrated in Figure 14–11. The spiral is formed in the reverse direction from the threaded part that is to be removed. In other words, a left-hand spiral is needed for a right-hand thread.

A pilot hole is first drilled into the broken portion. The diameter of the hole must be smaller than the root diameter of the thread. The drill size to use is generally given on the shank of the screw extractor.

Then, as the point of the spiral taper is inserted and turned counterclockwise (for right-hand threads), the screw extractor feeds into the hole. The spiral surfaces are forced against the sides of the hole in the broken part. The extractor and part become bound as one piece. The threaded portion then may be removed by turning the extractor.

## How to Extract a Broken Threaded Part

### Drilling a Pilot Hole

STEP 1 Select a screw extractor that is appropriate for the size of the stud or broken part that is to be removed.

STEP 2 Determine the size of the drill and the depth to which the pilot hole must be drilled. The diameter must be smaller than the root diameter of the thread. Drill the pilot hole.

**FIGURE 14–11** Right-Hand Thread Screw Extractor

### Extracting a Broken Part

STEP 1 Insert the screw extractor in the drilled hole. Turn gently and apply a downward force to set the extractor. (Figure 14–12 shows the position of the extractor in the pilot hole of a broken part.)

*Note:* Apply a pentrating oil or lubricant around the threads only. Keep the fluid away from the extractor surfaces.

STEP 2 Turn the extractor firmly and slowly in a counterclockwise direction for right-hand threads. Turn in the reverse direction for left-hand threads.

STEP 3 Clean and burr the workpiece. Run a tap through the threaded portion to touch up (finish) the threads. Recheck with a gage or mating part.

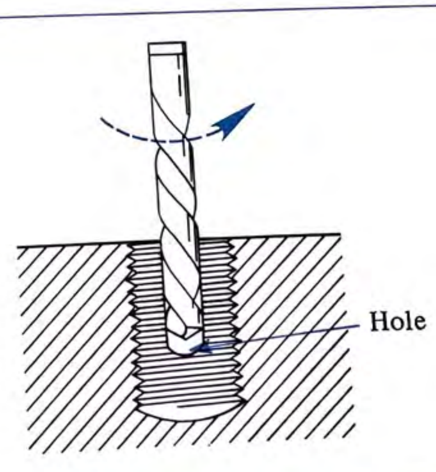



**FIGURE 14–12** A Screw Extractor Turned into a Pilot Hole Previously Drilled in a Broken Part

## Safe Practices in Cutting External Threads by Hand

—Analyze and correct the causes of torn threads. Torn threads indicate any one or all of the following conditions:
- –The jaws may be set too deep,
- –The threads are being cut at an angle,
- –The diameter of the workpiece is too large,
- –The cutting teeth are dull,
- –A proper lubricant (if required) is not being used.

—Remove burrs produced by threading. A beginning thread should be chamfered to start the thread squarely and easily.

—Position a workpiece as close to the vise jaws as possible. Use soft jaws where necessary.

—Exercise care in threading long sections. Turn a die holder from a position in which the hands do not pass across the top of a threaded part.

—Check adjustable dies as soon as practical to avoid undersized threading. Open the die and cut a full thread. Then adjust the die until the required fit is produced.

—Check a threaded hole against a gage or mating part for surface finish and class of thread (fit).

## TERMS USED IN SCREW THREAD DRAWING AND HAND THREADING

**Thread representation**
Graphic techniques of drawing threads in order to describe them accurately and provide full thread specifications. Pictorial, schematic, and simplified techniques of drawing and sketching a thread. A drawing with all features and dimensions.

**Standard dimensioning of a screw thread**
A set of symbols, forms, and technical data. A universally accepted dimensioning system that provides the full specifications of a screw thread.

**Screw pitch measurement**
Establishing the number of threads per inch in the Unified and National Form thread systems. Measuring the distance between teeth in millimeters in the ISO metric system. Gaging the pitch of a screw thread with a screw pitch gage, a steel rule, or by other measuring techniques.

**Dies (screw thread)**
A screw thread forming tool. (The cutting edges conform to a required screw thread.) Solid, split adjustable, or two-part adjustable screw thread cutting tools.

**Adjustable die (thread-size adjusting)**
A thread cutting tool that provides for variations in thread size. (Die segments may be expanded or reduced with adjusting screws.)

**Adjustable die guide**
A threaded part that screws into the cap against the two die sections (halves) to lock them in position. (The hole in the guide centers the work surface in relation to the die. The guide helps to start the threads squarely.)

**Nominal pipe size**
The inside diameter of a standard pipe.

**Screw extractor**
A hardened, spiral-fluted tool. (When turned into a drilled hole in the direction in which the screw thread can be backed off, the extractor turns the broken portion out of the mating part.)

## SUMMARY

Screw threads are drawn pictorially, schematically, or by simplified representation techniques to represent particular features. Dimensions provide further specifications about size, degree of accuracy (class of thread fit), depth or length, and so on.

The pitch of a screw thread in the Unified, American National, and ISO Metric thread systems may be measured directly with a steel rule or gaged with a screw pitch gage.

Three common forms of dies for regular straight threads and pipe threads include the solid die, split die, and adjustable split die.

Split dies and adjustable split dies are adjusted to the specific size of a workpiece. They are then locked in position. Adjusting screws in the die head or the die holder provide for a variation in pitch diameter.

The pitch diameter of a thread controls the fit of the thread. The die head is locked in a fixed position (pitch diameter) by a lock screw in the die holder.

The die is positioned over the workpiece and centered by a guide. The guide aligns the die in relation to the work surface.

Pipe thread diameters are expressed in terms of the inside diameter of the pipe. The tap drill size permits threads to be cut at full thread depth and at a taper of 3/4″ per foot.

The threading die halves of a pipe thread die are aligned with an index line on the die stock. The die halves are adjusted to produce a thread that meets specific job requirements. Once set, the threading dies may be used to thread a number of pieces.

## UNIT 14 REVIEW AND SELF-TEST

1. Explain the statement: A drawing provides full specifications for cutting and measuring a required thread.
2. Give three reasons why adjustable split dies are preferred over solid dies.
3. State three major differences between pipe thread dies and regular screw thread dies.
4. List the steps required to thread a workpiece on the bench using an appropriate size adjustable threading die.
5. Identify how a broken threaded part may be removed.
6. State three conditions that result in cutting torn external threads when threading by hand.

# WORKING WITH METAL

Cutting, Filing and Drilling

Ways to Shape Sheet Metal

How to Control Rust

Transformations Wrought with Heat

Chemical Coloring and Electroplating

# Hand-cut Threads Made with Taps and Dies

Threading is one of the classic ways to join metal to metal and metal to wood. Based on Archimedes' famous screw, this ingenious fastening method uses matched sets of spiraling grooves to interlock adjoining parts. Once threading was a handicraft; each craftsman cut threads with tools of his own design—which meant that few threaded parts were interchangeable. Today, threads are cut with high-carbon-steel taps and dies that come in standardized sizes. The taps cut threads inside a hole; the dies thread the outside of pipes or rods.

Tap and die sizes are based on one of two systems. The most common in the United States is the American National Thread System, adopted in 1911. In this system, thread sizes are specified as either NC, National Coarse, or NF, National Fine. The former is for general-purpose use; the latter, with more threads per inch, is for precision assemblies. The thread sizes, stamped on the tap or die, indicate the outside, or major, diameter of the thread, the number of threads per inch, and whether the threads are National Coarse or National Fine.

When the outside diameter is less than ¼ inch, taps and dies are marked with a gauge number, corresponding to the gauges of machine screws. For example, a tap stamped 8-32NC will cut threads for a No. 8 machine screw with 32 threads per inch in the National Coarse designation. A die stamped ¼-28NF will cut 28 threads per inch on a ¼-inch-diameter rod in the National Fine designation.

In the other system, which uses metric measurements, the designations are slightly different. The outside diameter is given in millimeters, and so is the thread pitch *(right)*, which corresponds to the threads-per-inch designation of the American National system. In addition, every metric tap or die bears a class number from 1 to 3, indicating tightness of fit; Class 1 is loose, Class 3 is close, or tight. In this system, tightness of fit is analogous to National Coarse and National Fine, in that it makes distinctions between precise and less precise work.

When you are cutting threads to match those on an existing screw, bolt or nut, you will need to measure the number of threads on the fastener with a screw-pitch gauge in order to select the correct tap or die. The gauge has blades toothed to fit between the threads on the existing fastener. One end of the gauge has blades corresponding to National Coarse, the other side to National Fine.

Before tapping a hole for a screw or a bolt, you may have to drill the actual hole *(page 24)*. This hole must correspond to the size of the tap and must be made with a special tap drill bit. Most tap-and-drill sets contain a tap drill chart to help you select the right drill bit; the charts are available in hardware stores. The chart will indicate, for example, that you would need a No. 29 bit for a hole to accommodate an 8-32NC tap.

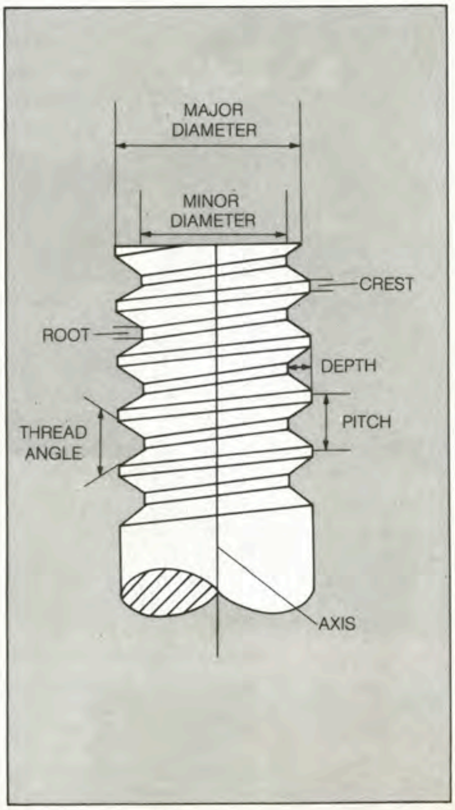
If you have never used taps or dies before, practice on a piece of scrap metal. The keys to cutting clean, accurate threads are to work with sharp taps and dies, and to keep the work square and well lubricated if lubrication is called for. When tapping, use a try square as a guide to keep threads straight; when cutting with a die, use the guide on the diestock. You should lubricate the tools and work area liberally with the appropriate cutting fluid when you are working with steel, copper, bronze or aluminum; brass and cast iron are cut dry.

When tapping, work slowly; taps are brittle and sometimes break. If this happens, you may be able to remove the broken pieces with a sharp tool such as a scribe, and start over with a new tap. But in most cases you will have to scrap the job. Similarly, if you cut ragged threads, you may be able to rethread the hole or rod—but generally the chances of correcting the damage are slim.

Thread cutting requires some precautions, since it produces sharp metal chips. Wear goggles at all times, and use a brush or a cloth to remove the chips from the threads and work surface. Make sure taps and dies are clamped securely. Taps are normally held in wrenches and are turned by hand. Dies are held in a special tool accessory called a diestock.

## The Profile of a Thread

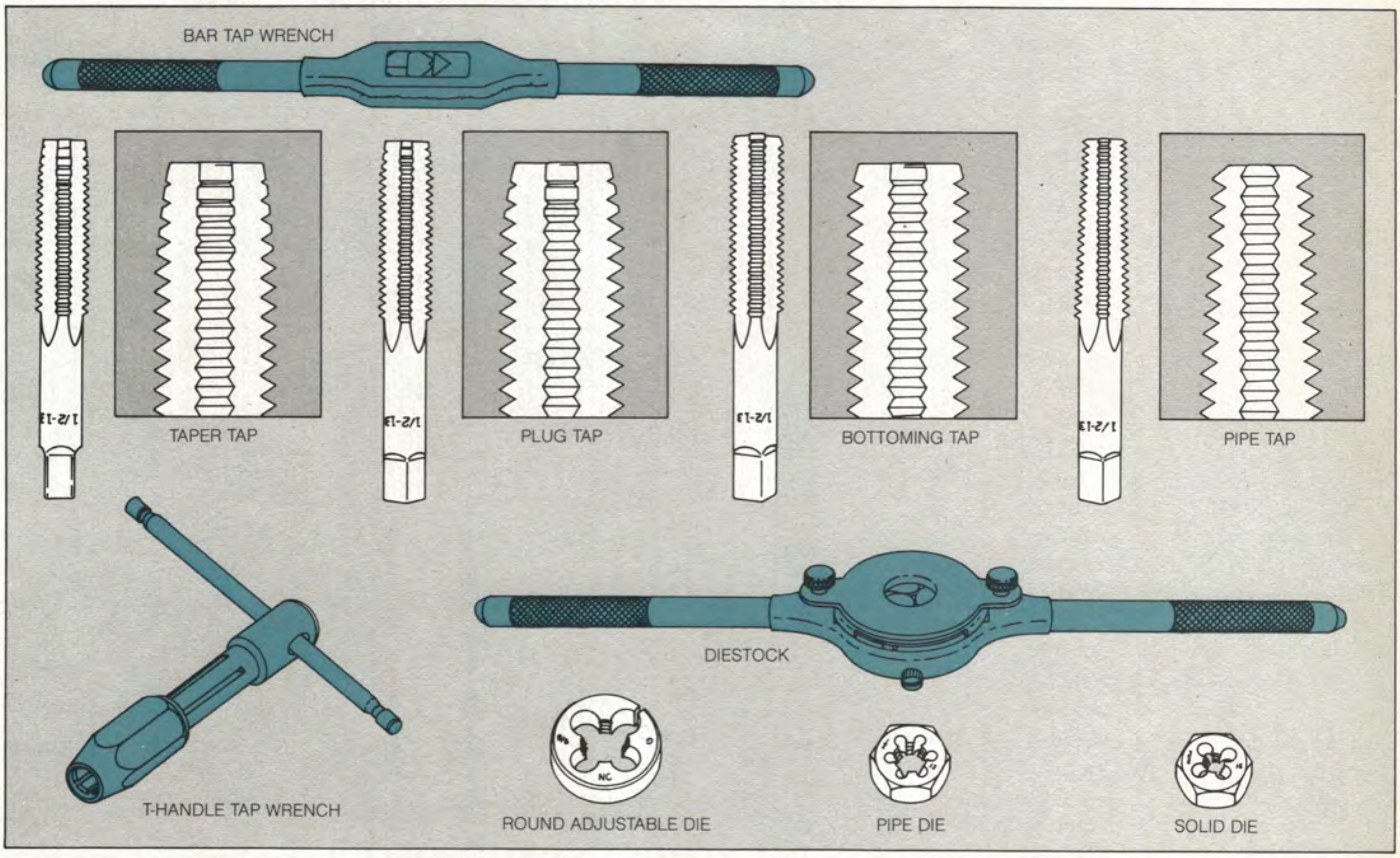
**A continuous cut with many parts.** The spiral-shaped groove that a thread cuts inside a hole or around the outside of a rod or pipe has its own special nomenclature. Its outside diameter, called the major diameter, is the largest span across the screw thread; it is the measurement that determines the width of the tap or die used in cutting. The minor diameter, sometimes called the root diameter, is the shortest diameter across the screw thread; it determines the size of tap drill bits, which should be slightly larger than the minor diameter of a thread. The crest is the peaked top formed by the two sloping sides of the threads; the root is the valley at the bottom. The thread angle is the angle of the sloping sides, which in the American National Thread System is always 60°. The pitch is the distance between the two crests of the thread; it is commonly expressed as a fraction based on the number of threads per inch—a screw with eight threads per inch, for example, would have a pitch of ⅛. Thread depth is the distance between the crest and the root, measured along an imaginary line bisecting the angle between two adjacent crests and running at right angles to the axis of the cylinder—either a rod or a hole—into which the thread is cut.



**Tools for cutting threads.** Standard taps for cutting threads on the inside of holes come in three styles, each designed for a specific purpose. A taper tap, or starting tap, used to start the threading process, tapers back from the tip for a distance of five to ten threads; the tapered tip aligns the tap in the hole during the initial stages of cutting. A plug tap tapers back only three or four threads and offers a greater cutting surface; it is often used after the threading pattern is established. A bottoming tap, with no taper at all, is used to carry the threading to the bottom of a blind hole—a hole that does not go all the way through the metal.

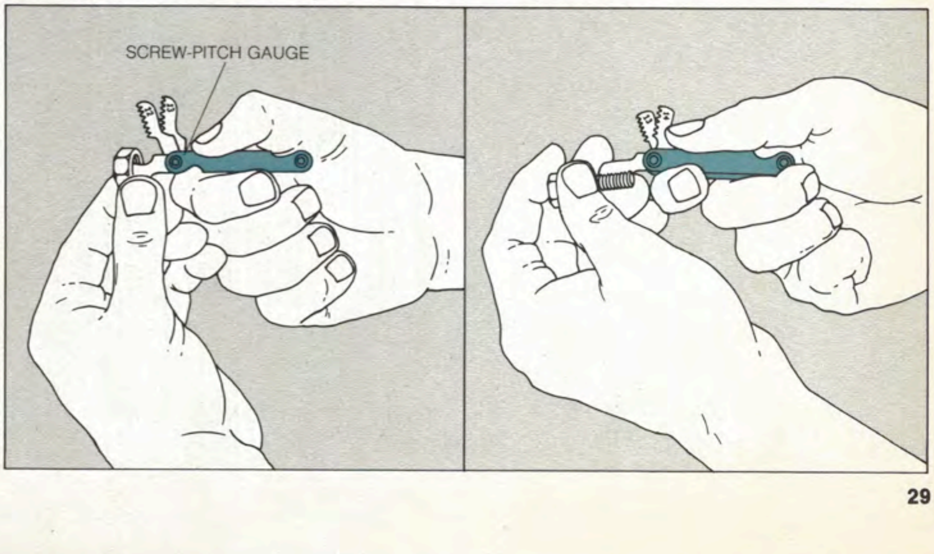
A special pipe tap, wider in diameter than standard taps and used for threading the inside of pipes, tapers all along its length. It produces a tapered thread, needed for a tight fit between sections of pipe to carry water, steam or gas. (Pipe taps for electrical conduit and for threading to connectors are straight.) Pipe taps are marked with the outside pipe diameter and NPT (National Pipe Thread). Taps are turned with tap wrenches—a T-handle wrench for smaller taps, a bar wrench for larger ones.

Dies are commonly of two kinds, hexagonal solid and round adjustable. There is a split on the adjustable die that can be widened or narrowed by means of a screw, for making fine adjustments within a given size—a useful feature in rethreading when you need a closer or a looser fit. On one side of a die, the opening is wider for one or two threads, so that the die can be firmly seated over the end of the rod at the beginning of the cut. Most pipe dies, like pipe taps, taper continuously from one side to the other and are stamped with the size of the pipe rather than with the size of the thread. Dies are held by means of a diestock, which usually has a guide for lining up the die with the pipe or rod, to ensure that the cut will be straight.




**A handy measure for matching threads.** To determine the proper tap size for threading a hole to match a bolt or screw, hold different blades of a screw-pitch gauge against the threads of the fastener until one blade fits. The number stamped on the blade is the number of threads per inch. Then measure the major diameter of the threads with calipers. The two numbers combined indicate the correct tap size for that particular bolt or screw.

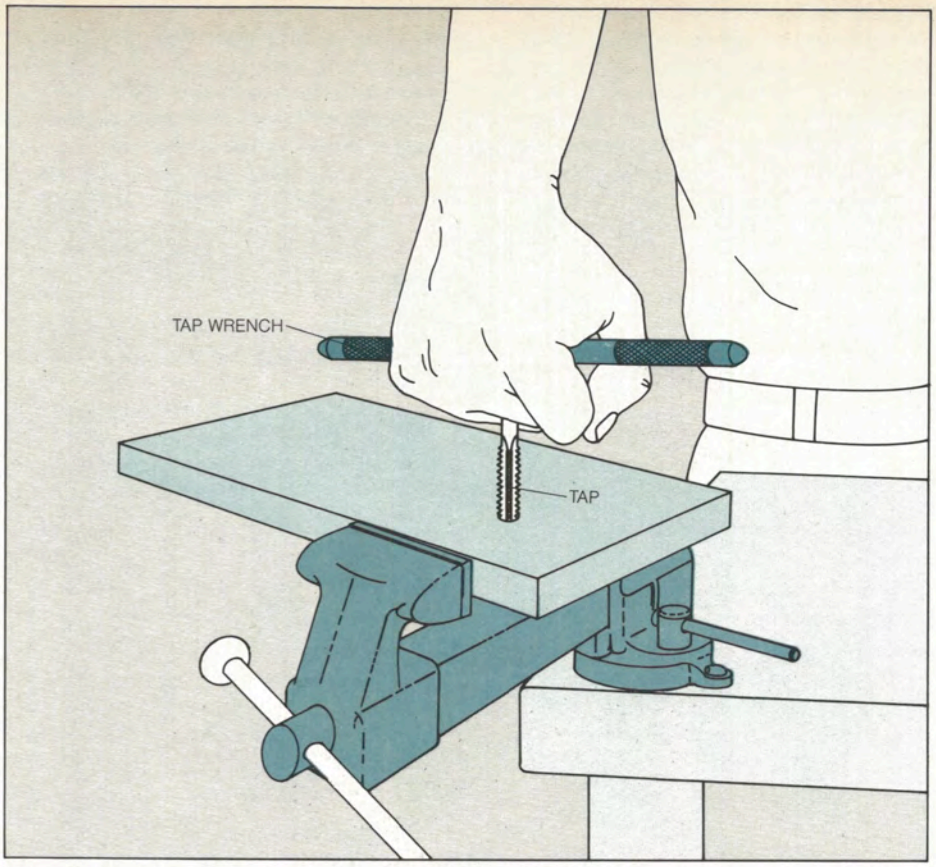
Repeat this procedure to determine the proper die size for cutting threads on a rod or pipe to match the threads of a nut or a threaded flange.



## Threading a Hole with a Tap

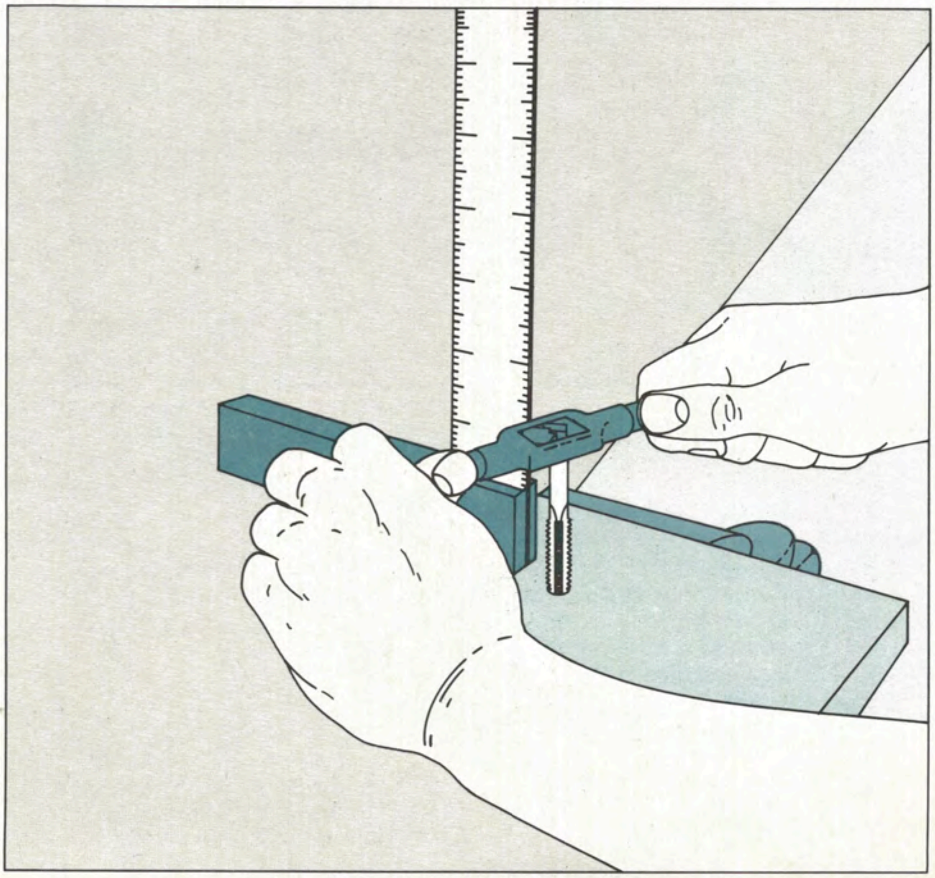
**1** **Starting the threads.** Clamp the metal workpiece in a vise, with the previously drilled hole in an upright position. Place a taper tap, held in a tap wrench, directly over the hole. To anchor the tap in the wrench, unscrew the chuck or the handle—depending on whether it is a T-handle wrench or a bar wrench—and insert the square end of the tap; tighten the wrench against the tap until the latter is secure.

Squirt cutting fluid *(page 24)* on the end of the tap, and spread it into the hole with a small brush. Then, with the tap lined up with the hole, grasp the wrench with one hand and press down, turning the tap clockwise. Maintain a steady pressure, and give the tap one full turn.




**2** **Checking the threads for alignment.** After you have cut the first thread, stand a try square on end about an inch away from the tap, positioning it so that the tap handle will touch the square on the next quarter turn. Grasping the wrench with both hands, step back and sight along the tap and square, to check whether the tap is vertical. If tap and square are not in alignment, unscrew the tap and straighten it.

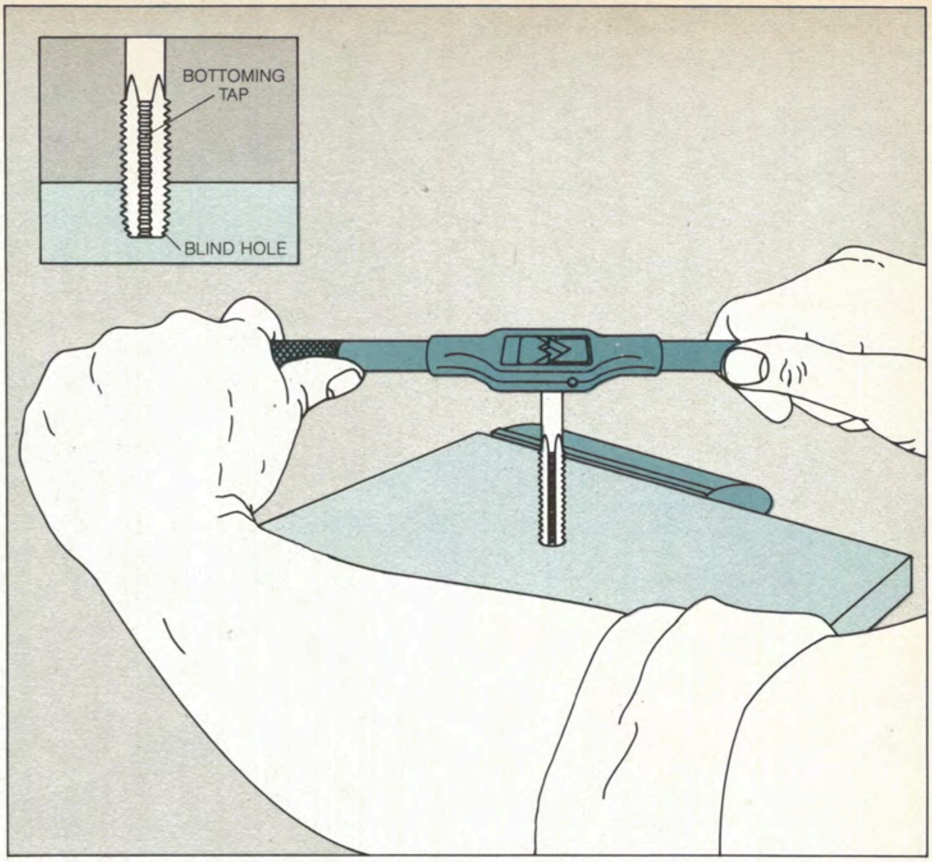
When you are satisfied that tap and square line up in this first position, give the tap a quarter turn and move the square a quarter turn beyond it. Once again sight along them to make sure the tap is straight, adjusting it again if necessary. Repeat this procedure two more times until you have completed one full revolution of the tap and have squared it at every quarter turn.



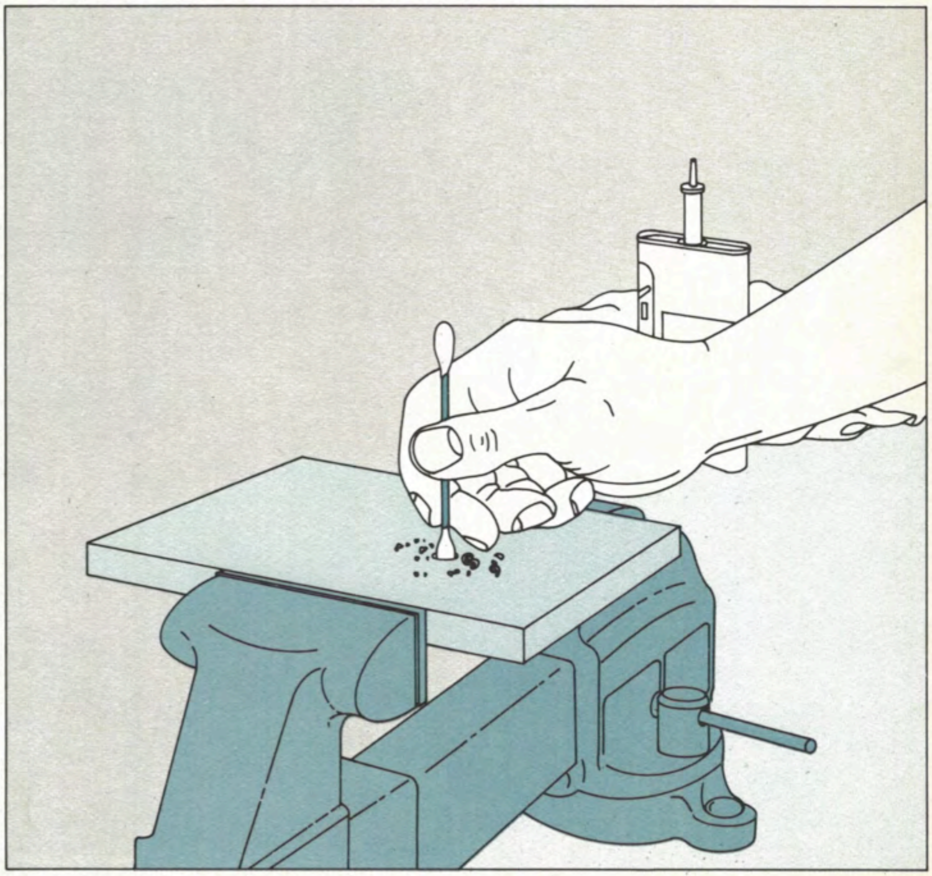
**3 Completing the threads.** When the tap is properly aligned, continue screwing it into the hole steadily and slowly. Do not use pressure; once engaged, the tap is drawn into the hole by its own cutting action. After every two full turns, back up the tap a quarter turn or half turn to snap off metal chips that catch on its cutting edges.

If the taper tap becomes difficult to turn, back it out and change to a plug tap. Be sure to lubricate the hole and the end of the new tap before placing it in the hole. When the hole is threaded, back out the tap carefully so that you will not damage the threads with the cut chips.

For a blind hole *(inset),* finish the threading with a bottoming tap. Screw in the tap, following the threads of the taper and plug taps, until it touches the bottom of the hole. Stop turning it immediately, then back it out carefully.

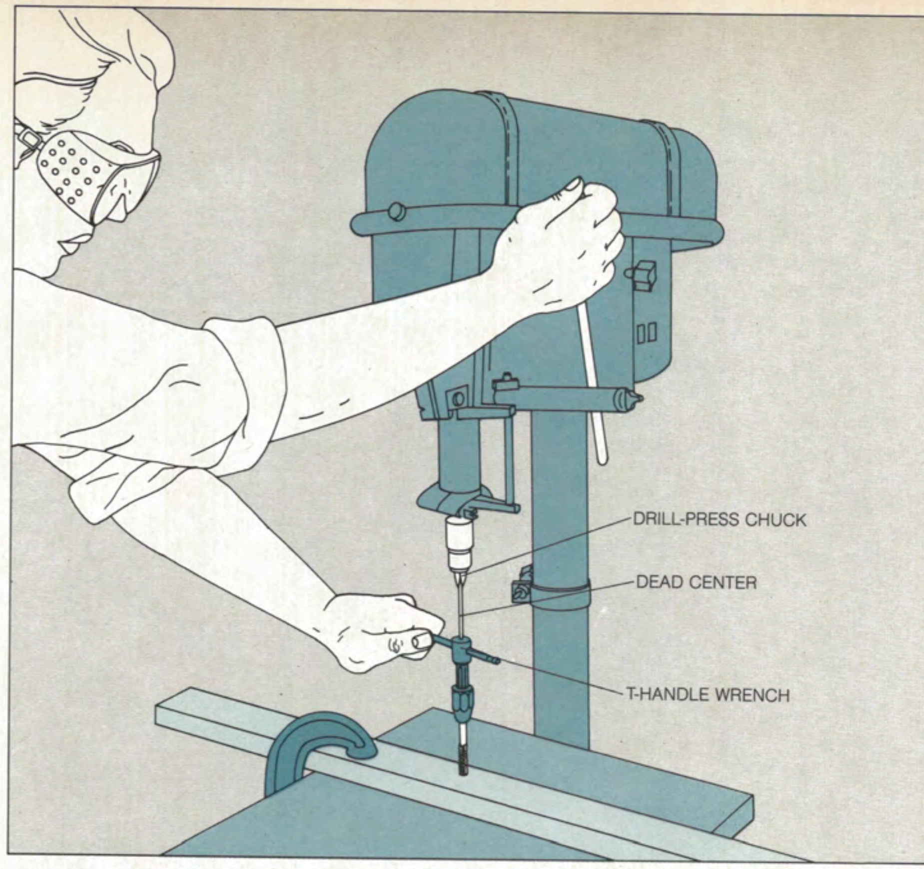



**4 Cleaning out metal chips.** Wearing goggles, gently blow chips out of the threaded hole and off the surface of the workpiece. Clean the hole with cutting fluid squirted on a cotton swab, and clean the workpiece of any remaining metal chips, using a cloth dampened with cutting fluid.



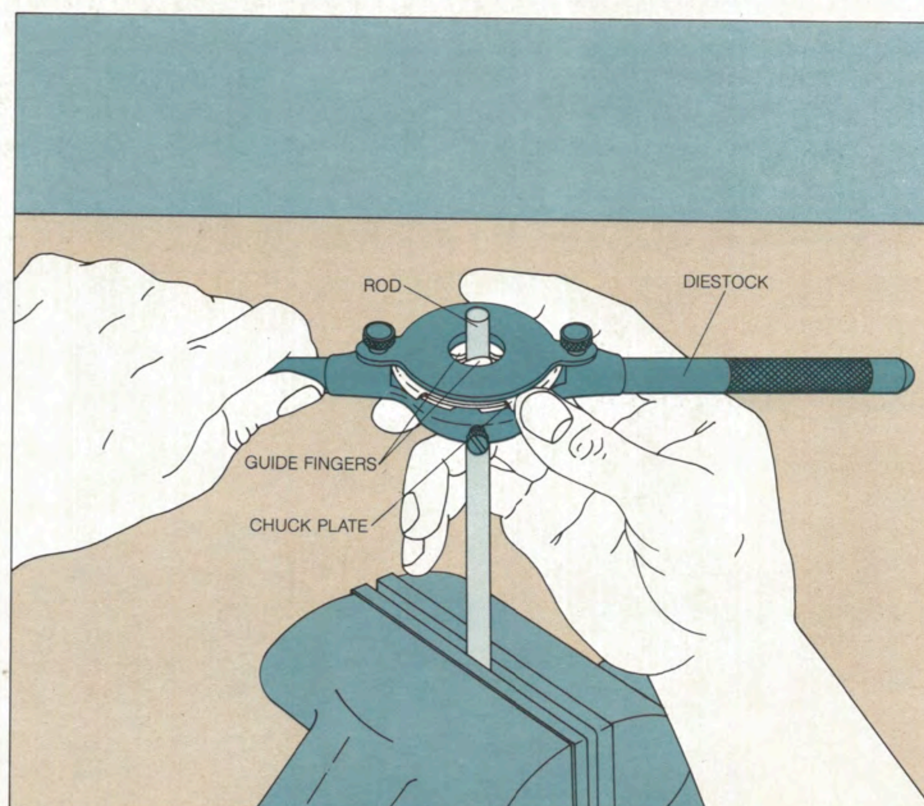
## A Drill Press Adapted to Center a Tap

**Setting up the drill press.** Clamp the metal workpiece to the drill-press table with a C clamp, placing the predrilled hole directly beneath the center of the drill's chuck. Put a dead center—a metal rod with a pointed tip—into the drill chuck. Insert a taper tap in the chuck of a T-handle tap wrench and place it in the hole. Lower the chuck until the dead center is centered over the indentation in the top of the tap, repositioning the workpiece if necessary. There is no need to check the tap for alignment, since the drill press aligns it automatically. Grasp the wrench handle and turn it clockwise to thread the hole. Once the tap is started, raise the drill-press chuck, remove the dead center and finish threading the hole by hand as on pages 30-31.

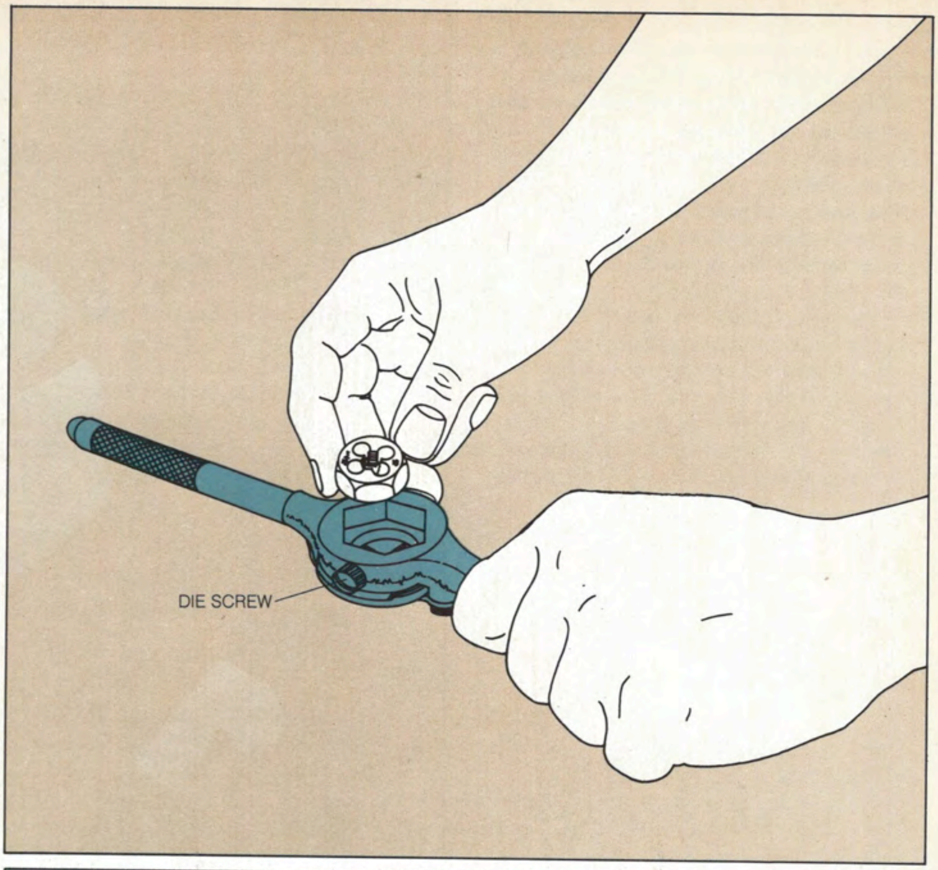



## Threading a Rod with a Die

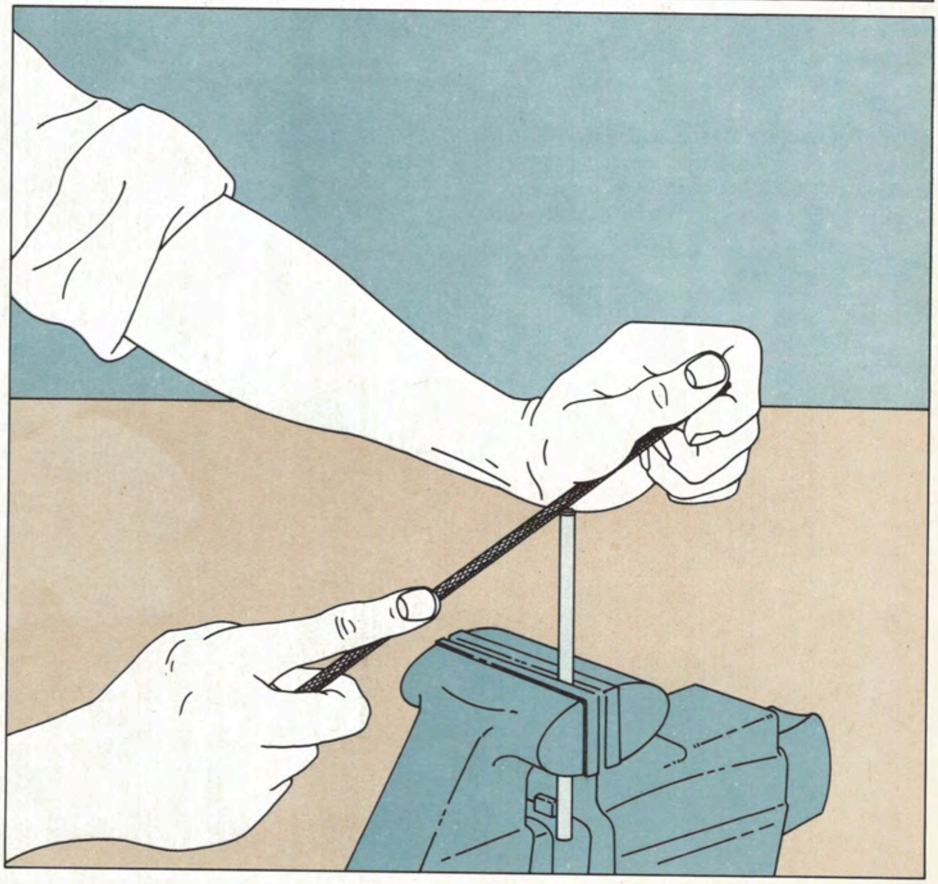
1 **Adjusting the diestock guide.** Loosen the two guide screws on the base of the diestock that hold the chuck plate and guide fingers in place. Turn the chuck plate clockwise to open the fingers. Slip the diestock, chuck plate up, over the rod, which has been clamped in a vise. Swivel the chuck plate counterclockwise until the guide fingers touch the rod. Open the fingers slightly, just enough to slip the diestock off the rod. Then tighten the two guide screws again, to hold the guide fingers in place.



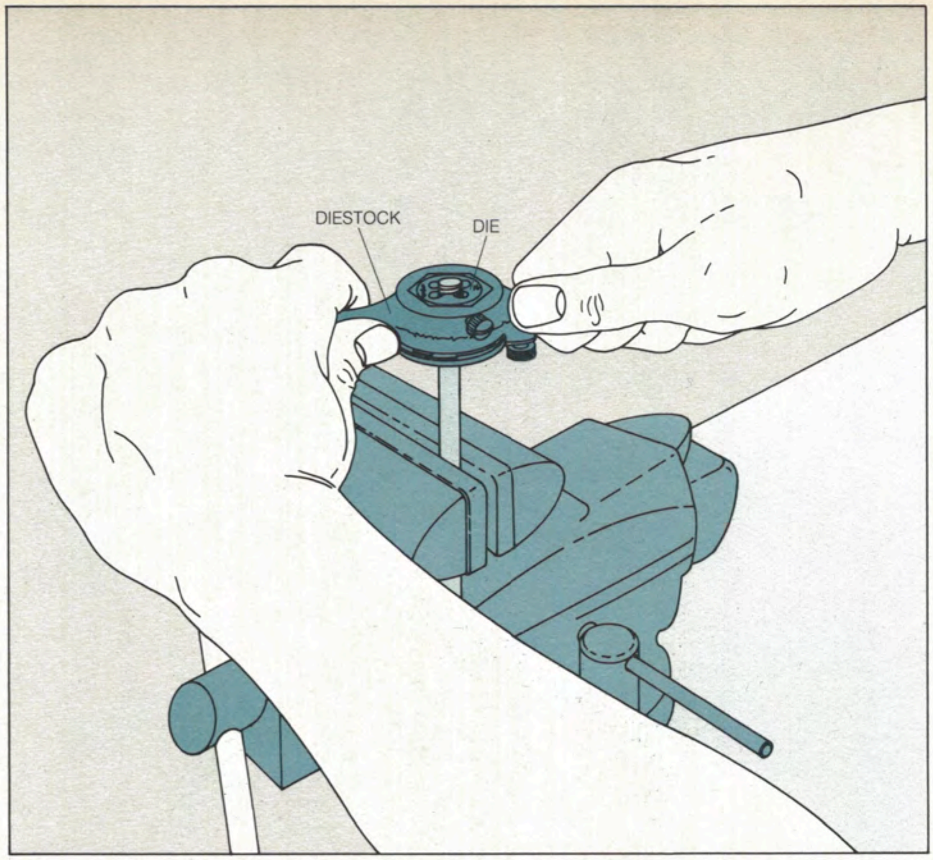
**2 Inserting the die in the diestock.** Hold the diestock, chuck plate down, and loosen the die screw on the side of the diestock. Insert the die in the depression designed to receive it, placing the tapered end of the die's cutting threads face down, against the guide fingers. Then tighten the die screw.



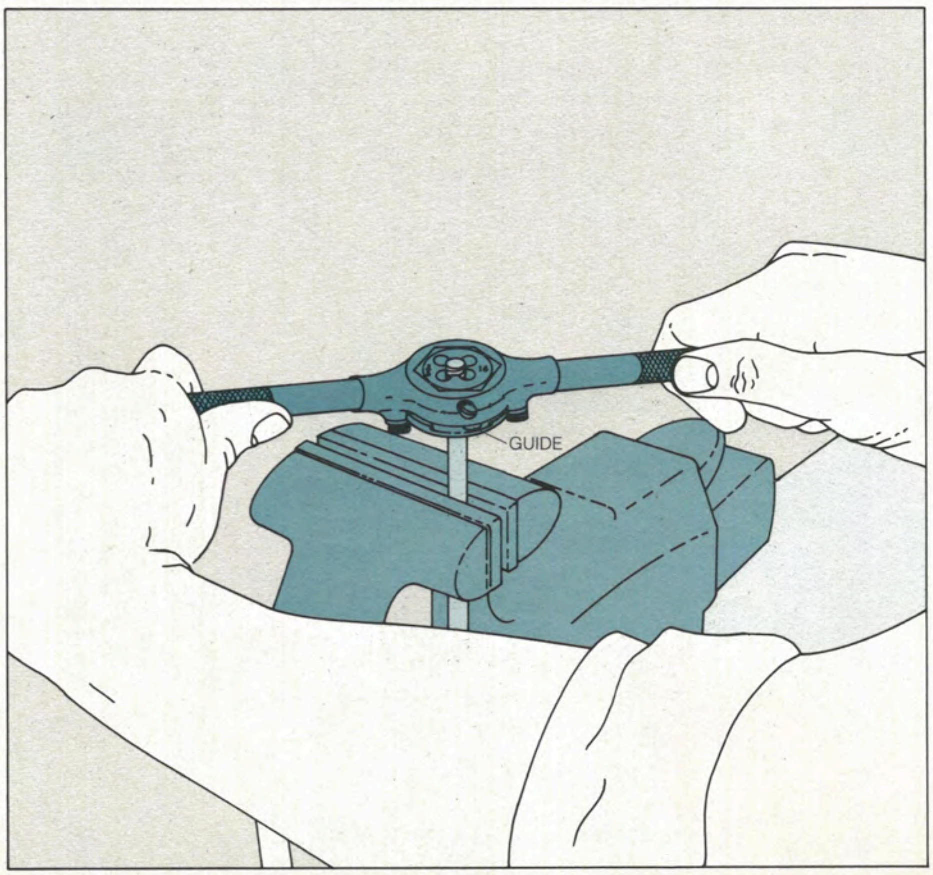

**3 Beveling the end of the rod.** To allow the die to grasp the rod tightly, file the bevel around the edge of the rod, using a 10-inch half-round medium-coarse file. Grasp the file at either end and, holding it at about a 30° angle, draw it across the edge of the rod, keeping this angle as nearly as possible around the entire edge.



**4 Starting the threads.** Scratch a mark on the rod at the point where you want the threads to end—the depth of the hole into which the rod will fit. Clamp the rod in a vise and place the diestock and die over it, lining up the bottom of the guide with the top of the rod. Turn the chuck plate until the fingers grip the rod tightly; then tighten the screws. Grasp the diestock handles near the die, press down firmly and turn the diestock clockwise to start the threads.




**5 Finishing the threads.** Move your hands to each edge of the diestock and continue threading the rod with a steady motion, backing up a quarter turn to half turn every two full turns, to snap off metal chips. When the guide reaches the mark showing the desired end of the threads, back the die slowly off the rod. Turn the diestock over, put it back on the rod and cut the remaining threads to reach the scratch mark. Clean away any metal chips.



# Factory-made Fasteners

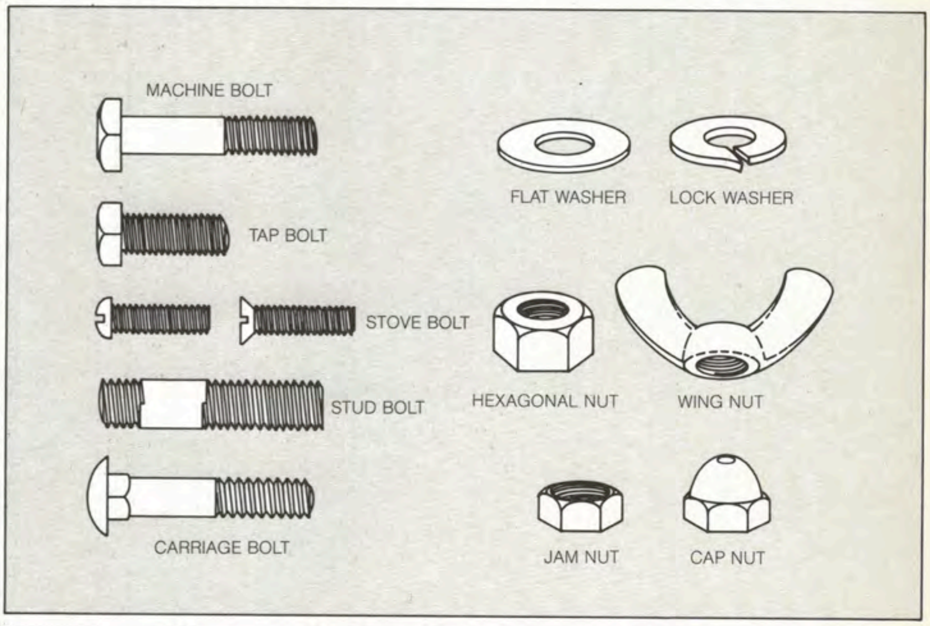
When metal parts are made for disassembly or are too thick to be pop-riveted *(page 57)*, the standard way to fasten them is with bolts or screws in threaded holes. These threaded fasteners come in a variety of metals—steel, brass and aluminum—and some have special finishes, such as oxide coating, to prevent corrosion. They are sized by diameter and length, and the length does not include the head—except in the case of oval- and flat-headed machine screws. Threaded fasteners are also graded according to the strength of the metal from which they are manufactured.

The distinctions between bolts and screws intended for use with metal are not as clear-cut as those for wood. Machine screws, for instance, have blunt tips, and stove bolts have slotted heads. But generally bolts are used for heavier work and where the work is accessible from both sides; they are used with nuts. Screws are intended for lighter work that is accessible from only one side. They can be used with or without nuts—except that the hexagonal-headed cap screw is always used with a nut.

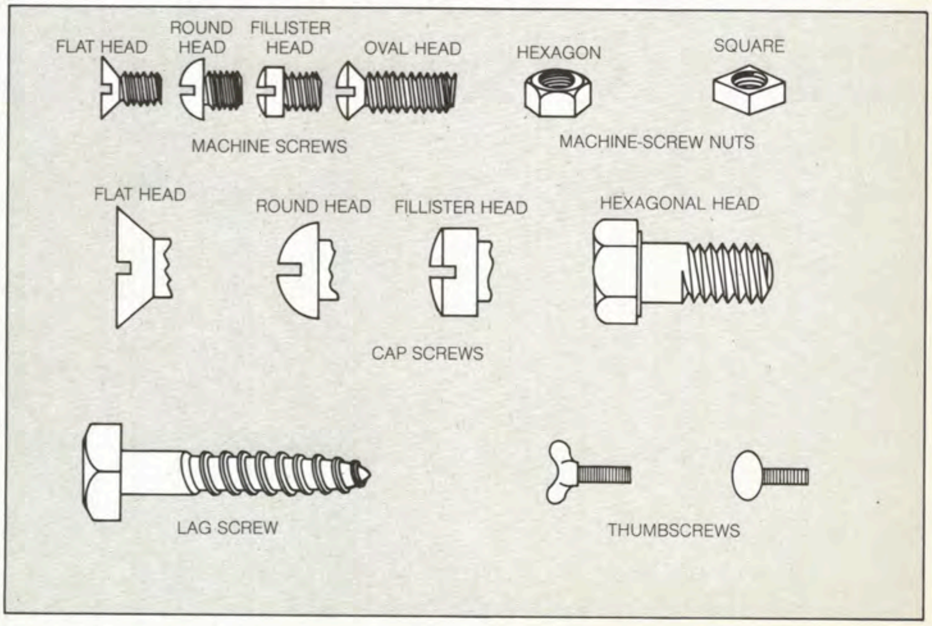
In attaching bolts and screws, use the correct tool. Bolts and nuts should be tightened with wrenches, not pliers. Screws and slot-headed stove bolts should be tightened with screwdrivers whose tips fit snugly into the head slots.

**Metalworking bolts, washers and nuts.** Machine bolts, used in heavy-duty assembly, have either hexagonal or square heads; common sizes include diameters from ¼ to ½ inch and lengths from 1 to 6 inches. They are used to join two pieces of metal, only one of which is threaded. Tap bolts are similar to machine bolts and come in the same sizes, but they are threaded along the entire body; they are used to fasten two threaded pieces of metal, achieving a close fit. Stove bolts, smaller than machine or tap bolts, have round or flat heads and are commonly available in diameters from ⅛ to 5⁄16 inch and lengths from ⅜ to 3 inches. They are used mostly in stoves and are tightened and loosened with a screwdriver. Stud bolts are used to fasten two parts together when you may wish to remove one part without removing the bolt from the other part; they have an unthreaded center and come in the same size as machine bolts. Carriage bolts, used for joining metal to wood, have round heads with square collars at the top of the shank and are available in the same sizes as machine bolts.

Common bolt nuts are hexagonal so they can be tightened with a wrench. A cap nut covers the bolt end. Wing nuts are for parts that are disassembled frequently. The thin nut called a jam nut is often used as a washer, to lock a bolt and nut in place; it may also be used alone for a tight but adjustable fit. Nuts come in the same diameters as bolts. The two common types of washers, the flat washer and the lock washer, also come in standard sizes; lock washers are made to press against the work and the nut.




**Metalworking screws.** Machine screws have four different head styles—oval, fillister, round and flat. The common sizes are No. 8 through No. 14; these range in diameter from 3⁄16 to 5⁄16 inch and from ½ to 4 inches long. The hexagonal nuts sometimes used with them are like those for bolts but are smaller; square nuts are also used. Cap screws are threaded only partway along the shank and are used to join two parts where only one part has a tapped, threaded hole. They range from ¼ to 1½ inches in diameter and from ½ to 6 inches in length. Thumbscrews, used when parts need to be taken apart, come in the same sizes and widths as machine screws and have either a flat or a winged head. Lag screws, also called lag bolts, have a bolt-type head but are threaded like a screw and are used to attach metal to wood. They are available in the same sizes as carriage bolts.



# JEWELRY

## CONCEPTS AND TECHNOLOGY

OPPI UNTRACHT AUTHOR OF "METAL TECHNIQUES FOR CRAFTSMEN"

# SCREWS, BOLTS AND NUTS, AND SCREW JOINTS

## Mechanical cold fabrication by torsion-pressure holding systems

### SCREWS

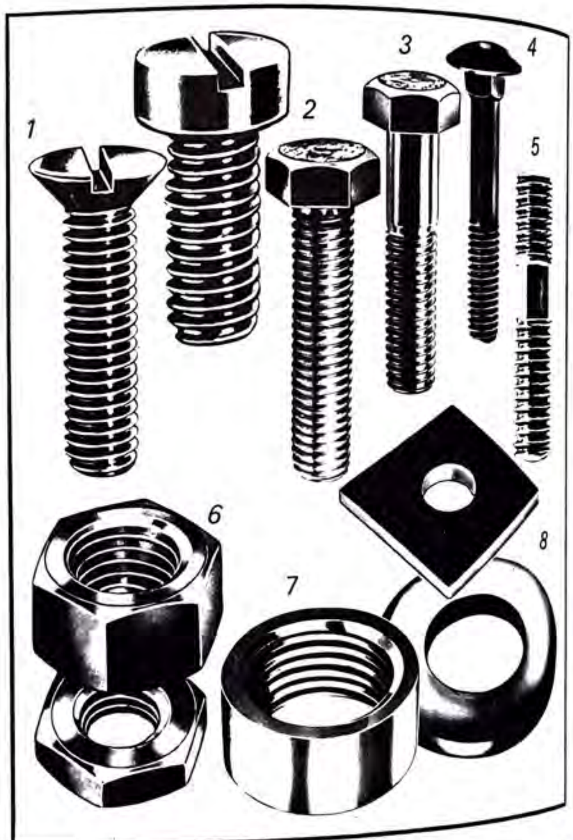
A *screw* is a mechanical fastening device that applies pressure on the parts being joined, the pressure acting to hold them together. The basic concept of *any mechanical device* is that it serves to transmit and modify motion and/or force to produce a desired effect or work. The screw, in several forms, does exactly that.

The mechanical system of joining jewelry parts by means of screws alone, or screws and/or bolts with nuts can be resorted to not only when joining metal to metal, but when joining *dissimilar materials,* such as metal to plastic, metal to wood, metal to ivory, etc. Screws are also useful in cases where heat cannot be applied, for example as when joining a separately made enamel-ornamented unit to a larger work, or a stone set independently in a separate metal bezel to a ground of metal or another material by means of a screw previously soldered to its back. Screws are sometimes used to take the place of a rivet when the work is too delicate to withstand hammering. Screws have the unique advantage of being able to be removed to disassemble work for purposes of repair, or to repolish otherwise inaccessible areas, such as a reflective backplate. Screwheads are often concealed in jewelry, but today they are at times deliberately exposed as a decorative joining device.

#### THE PARTS OF A SCREW

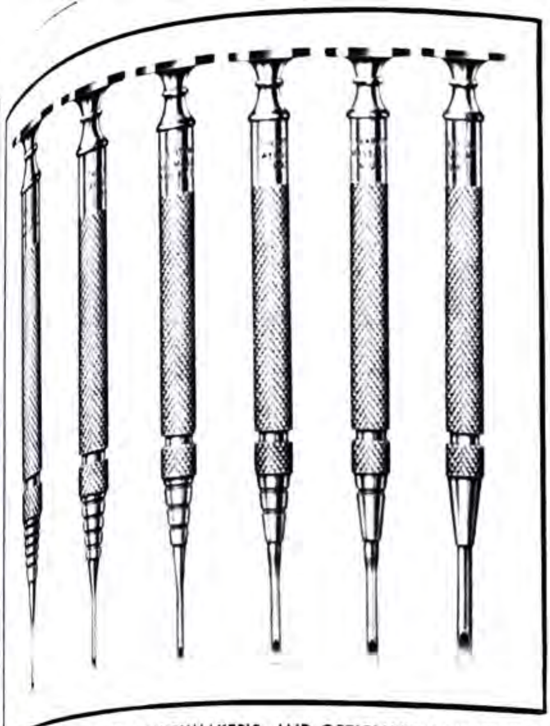
In its common form, a screw consists of a *slotted head* which can have any of several shapes, and a cylindrical *shank* or *spindle* that is grooved in its total or partial length with a helical spiral consisting of one or more *threads,* also called *worms* or *ribs* in some cases. The thread utilizes the concept of the *inclined plane,* which classifies the screw as a *simple machine.* (The six simple machines are the screw, the lever with fulcrum, the wheel and axle, the pulley, the inclined plane, and the wedge.)

The same mechanical principle of the inclined plane in the form of a screw is utilized in a holding device such as a clamp or vise, in the transmitting of motion as in a micrometer, and as a provider of power as in the operation of a tool such as a lathe. In the screw, the inclined plane winds in a helical spiral around the solid metal or hollow cylinder shank, and becomes the threads or ridged ribs which are uniform in section, but possibly different in shape, depending on the work they are to perform. It is the thread's inclined plane that converts the screw's rotation into *straight-line motion,* and the holding power of screws, and bolts and nuts depends upon the threads.




10–28 SCREWS, BOLTS, NUTS, AND WASHERS
1. *Metal screws* with slotted or grooved heads, the first with a *cone or flat head,* the second with a *cap head.*
2. *Hexagonal-headed screw-bolt* with full thread.
3. *Hexagonal-headed bolt* with half threaded and half plain shank.
4. *Oval-headed bolt* with square base for setting into a square hole to immobilize the head, with half threaded shank.
5. *Headless* or *grub screw* with plain center to allow tube threading from both ends.
6. *Hexagonal screw* or *bolt nuts,* wide and narrow.
7. *Sleeve nut* or *screw coupling.*
8. *Square washer; round washer.*

*Right-hand threads,* when seen from the head, turn in a clockwise direction, while *left-hand threads* (commonly



10-29 JEWELER'S, WATCHMAKER'S, AND OPTICIAN'S SCREWDRIVERS These are adapted to fine, delicate work on small screws. The knurled steel tubing bodies and concave swivel knobs provide for good grasping. The tempered steel blades are held in chucks whose number of grooves designate blade sizes. They vary in width from 0.025–0.100 in. For convenience in carrying, the blade can be reversed into the body. *Photo: Courtesy L. S. Starrett Co.*

used in jewelry in the East) turn counterclockwise. When the threads are *external* they are called *male threads,* and when they are *internal, female threads.* Any round hole of a proper size in solid metal can be threaded internally to match an externally threaded screw, but the most common form of internal threading occurs in a *nut.* This is a square- or hexagonal-sectioned metal part, perforated with a hole that contains the female thread, its size coordinated with the screw or bolt with which it is meant to mate. (Bolts and nuts are discussed on p. 427.) Screws and bolts used for metal are cylindrical and have blunt ends, but screws used for wood are tapered and have pointed ends. Wood screws form their own internal threads in the material as they enter.

Screws are inserted in the threaded hole made to receive them, and are rotated by the aid of a *screwdriver.* A screwdriver is used to drive or force the screw spirally in place, called "screwing it home," by inserting its wedge-shaped end into the slotted groove of the screwhead, each turn causing it to advance. Jewelers and watchmakers use very small screws which require specially made miniature screwdrivers to tighten them. One such screwdriver consists of a single knurled handle with a chuck into which blades of various sizes can be inserted to allow the interchange of blades.

SCREW THREAD FIT As both parts being joined are threaded with mating threads, they mesh as the screw advances until, when fully wound home, the screwhead comes down tightly on the parts joined, or in the case of a bolt and nut, until both come tightly together bringing two-sided, clamping pressure upon the parts being joined. A *close screw thread fit* is one in which there is a minimum of shake or play, and the interference of the metal is zero. Continuing the screwing torque pressure beyond this point may cause the threads to wear out or become stripped, which renders the screw useless. Therefore, you must learn to sense the correct moment when to stop exerting pressure, when maximum torque tension exists.

## SCREWHEAD TYPES

Most screws have a *slotted* or *grooved head* into which the screwdriver is inserted to wind and tighten the screw, or to loosen and remove it. The head can be of several shapes, depending on how the screw is to function. Some of these are the following:

*Cap:* A straight-sided, cylindrical form.

*Flat (cone):* A cone shape tapering toward the shank, commonly used with a countersunk surface to make the head flush with the plane of the work surface.

*Round:* A semicircular head that projects above the surface.

*Oval:* A curved, low-profile shape that projects upward less than a round head.

*Headless:* Without a head, the solid or tube shank itself being slotted, driven home either flush, or below the surface (also called a grub screw). In the latter case, the remaining circular depression may be filled with a tight-fitting round *plug* of the same or contrasting metal to make the screw presence invisible. So-called *headless screw rivets* are short, threaded cylinders whose shank length is a fraction more than the thickness of the parts joined. Once threaded in place, both ends are hammered to form shallow or flush heads that are then permanent.

*Decorative:* Any ornamental head shape attached to a screw or bolt shank.

*Thumb:* An oval, flat or concave, knurled or smooth-surfaced projection joined perpendicularly to a screw or bolt shank that permits tightening it with the thumb and forefinger. It is often found on tools such as the jeweler's saw frame, and clamps or holding devices of various types that are tightened manually.

## THE PARTS OF A SCREW THREAD

*Crest:* The top point where adjacent sides of the inclined plane of a thread meet.

*Root:* The bottom surface where adjoining adjacent sides of the thread form a groove.

*Pitch:* The distance from any crest to the adjacent one, measured parallel to the shank axis.

*Lead:* The amount of axial movement of any point on the screw thread during one complete revolution.

*Single thread:* A screw having a single helix crest around the shank, from beginning to end.

*Multiple thread:* A screw with more than one helix around the shank, such as a *double thread* which has *two* in which the lead between each distinct thread is twice as long as the pitch.

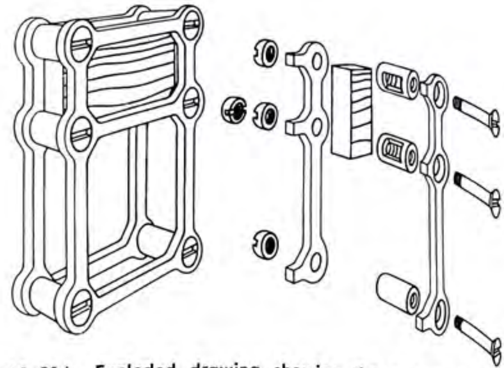
Threads are divided into two basic types: those used for *fastening,* and those used to transmit *power* and *motion,* as in lathe lead screws, vises, and clamps.

10–30 NOMA COPLEY, U.S.A. "Screw Head." Cast 18K gold cuff links in the form of cone- or flat-headed screws; with wire links. *Photo: Tracy Boyd*

10–31 JOËL DEGEN, England. Four rings using the cold fabrication system of screws and threaded parts to hold units together.

*Top left:* Ring of titanium and stainless steel with striped agate sandwiched between them.
*Top right:* Ring with two blue anodized titanium sheet units separated by silver tube spacers, joined by gold flush-headed screws with stainless steel shanks. The green-dyed moss agate stone is held by four tubes notched to accommodate it. Exploded drawing showing the parts used in the assembly of the ring at *left.*
*Bottom left:* Ring with 1½ct emerald-cut diamond, set in a white gold cup on a yellow gold shank. The channel-grooved outer titanium discs and the cup edges hold the stone. Stainless steel flush-headed screws are threaded into holes tapped in the gold shank.
*Bottom right:* "Worry" ring. Constructed with an upper cylinder that revolves by a shielded ball bearing placed inside. Above this, a tubular structure holds the upper round diamond. Around the cylinder are 12 baguette diamonds held in place by holes in two titanium discs. Below is a disc with 12 tapped holes which hold the 12 screws circling the central diamond, and bind the entire structure. The gold shank is faced on both sides with titanium discs fastened by flush-headed stainless steel screws. *Photos: Joël Degen*

10–32 JOËL DEGEN, England. Bangle bracelet of three metal layers: stainless steel, silver, and blued titanium. Pierced hole diameters are slightly smaller than those of the lenticular-shaped red carnelians. Once parts are screwed together, the stones hold in place. Screws pass from the steel side to engage the titanium sheet in which meshing holes are threaded. *Photo: Courtesy Crafts Advisory Committee, London*



10–31A Exploded drawing showing the parts used in the assembly of the ring at *left.*

## Thread types

| Thread name | Angles between sides of thread | Description |
|---|---|---|
| *Fastening threads* | | |
| American National Standard | | |
| Coarse (ANC) | 60° | squared-off crest, rounded root |
| Fine (ANF) | 60° | squared-off crest, rounded root |
| British Association Thread (BA) metric | 47.5° | rounded crest and root |
| V-thread, American | 60° | sharp crest and root |
| Whitworth (BS), British | 55° | rounded crest and root |
| European, metric | | |
| French (NF) | 60° | rounded crest and root |
| German (DIN) | 60° | rounded crest and root |
| Swiss (VSM) | 60° | rounded crest and root |
| Unified National System U.S.A., U.K., Canada, 1948 | | |
| Coarse (UNC) | 60° | rounded crest and root |
| Fine (UNF) | 60° | rounded crest and root |
| International Standards Organization (ISO), metric, 1963 | | |
| Coarse (ISOC) | 60° | flat crest and rounded root |
| Fine (ISOF) | 60° | flat crest and rounded root |
| *Power and motion threads* | | |
| Acme | 29° | squared-off crest and root |
| Buttress, one face vertical, other angular | 45° | squared-off crest and root |
| Square | 90° | squared-off crest and root |

Commercial metal and wood screws, and bolts and nuts are available in many sizes and head shapes, made of iron, steel, copper, brass, bronze, aluminum, and nylon. Small sizes suited for use in jewelry are available from watchmakers' suppliers. Screws in precious metals are also available. All screws and bolt and nut types can of course be made by the jeweler from any metal according to need, by methods described below.

## BOLTS

*Metal screws* pass through parts and are seated in the drilled and tapped mating threads that have been prepared to receive them. Tapered wood screw threads form their own threads as they penetrate the material. Bolts are different from screws in that normally they pass *completely through* an unthreaded hole in the parts joined without being screwed into them, and hold the parts together by the help of a nut wound onto the end of the shank. When tight, friction between the thread and the nut, as well as the helical pressure on the nut wound on the bolt, prevents its becoming loosened, unless excessive movement or vibration occurs. Bolts have special threads, but may also be threaded with normal screw threads, in which case they are sometimes called *screw bolts*.

*Bolt heads* commonly are square or hexagonal to allow them to be gripped with a wrench, or they may be of several other shapes similar to those used on rivet heads. (See Rivet Head Shapes, Chapter 10.) They may also have a head of any decorative shape when visible and used in jewelry.

*Washers* may be used with screws, bolts, and rivets. They are plain or decorative rings of metal, leather, nylon or another material, and are placed between the screw, bolt, or rivet head and the upper work surface. Their purpose is to form a seat for the head, to protect the work surface against which they are drawn by increasing the area of pressure (useful when using thin metal), to prevent a tightened head from being pulled through the opening, and to prevent loosening from vibration by locking the screw or bolt in place through an increase in the area of friction.

10–33 PETER SKUBIC, Austria. Stainless steel rings based on the bolt and nut concept. Height 42 mm. *Photo: Peter Skubic*

## NUTS

Nuts are square or hexagonal blocks of metal, perforated and internally threaded, and are used at the end of a screw or bolt to draw and hold parts together. The *sleeve nut* is an internally threaded cylinder made of tubing, also called a *screw coupling* or *screw socket*. The threading can be all in the same direction, or half right and half left. Such a coupling can be used to join two threaded wire ends, rods, or tubes, one from each side.

# CONSTRUCTION

## MAKING A PSEUDOSCREW

Screws are believed to have been invented by about the 4th century B.C. It is possible that the idea was inspired by nature in the form of shells whose eroded, exposed inner spiral structures were thrown up on beaches. In Roman times, screws were made by winding a triangular wire around a cylindrical rod, with one flat side against the rod. This wire was also used as a guide to file, chisel, or gouge the spiral groove into the shank cylinder.

10–34 *Left:* DETAIL OF THE CLOSING DEVICE contained within the back bead that divides in half. The psuedoscrew is made of a wire wrapped spirally around a wire shank, which fits a spirally wrapped screw cylinder formed in the screw's grooves, then mounted within the second bead half. *Photo: Jan Olsson*

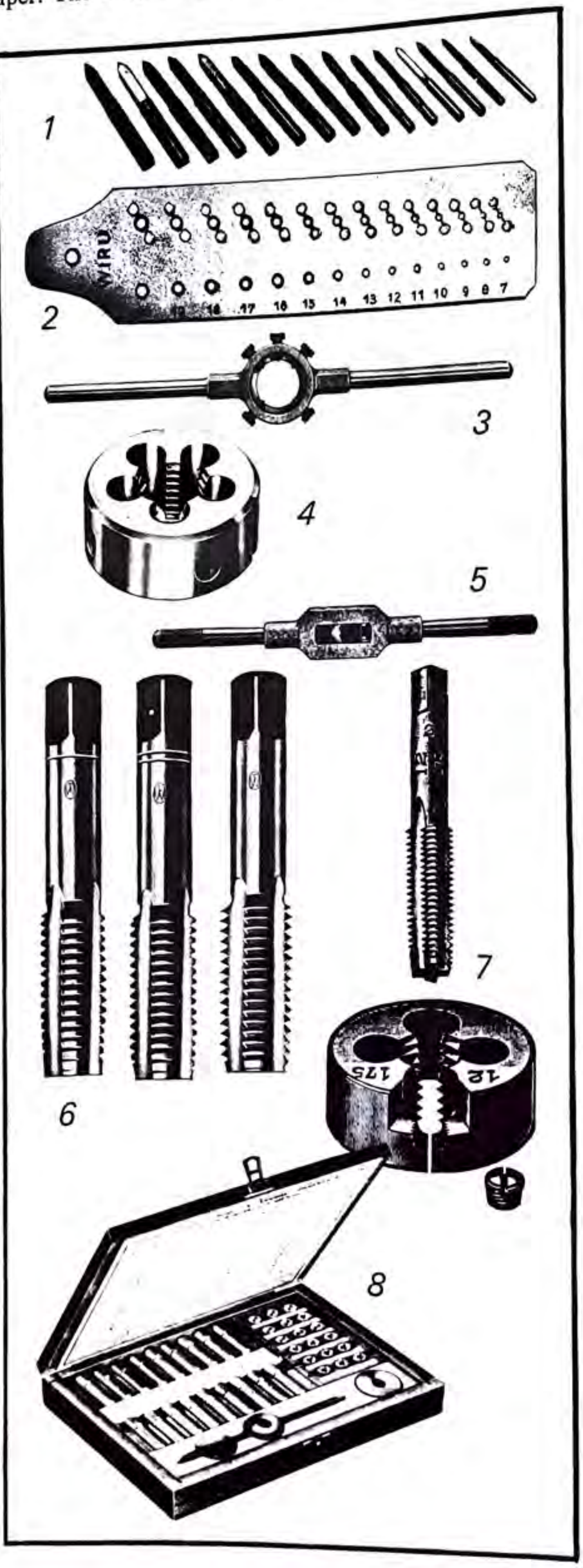
10–35 *Right:* BERNDT LINDHOLM, Finland, maker; ANDERS HÖGBERG, Sweden, designer. Necklace of square-wire silver openwork spheres in graducted sizes, decorated with small, concave gold discs, separated by small gold beads. *Photo: Jan Olsson*

A similar, simple device that functions in concept like a screw and sleeve nut is often used today in India on jewelry as a closing device for belts and bracelets. No *screw plates* or *taps*, the tools normally used today for forming a thread on screws and in nuts, are needed. First cut a suitable length of round wire for the shank core, and solder on a head, often a round, solid ball. Starting at this head, tightly wrap a round wire in a close clockwise spiral around this shank to its end. Solder the start and the end of the spiral to the core wire to keep it from moving on the shank core. The wrapped wire is now equivalent to the *external* or *male screw*. It must mate with an *internal* or *female screw*, normally contained in a nut. Carefully wind the same gauge round wire spirally clockwise onto the groove depressions of the spiral on the male screw, and cut off the end. This outer spiral is equivalent to the nut screw or a sleeve nut. It is easily removed from the male screw by unwinding it counterclockwise with the fingers, like a nut. The resulting nut-spiral can then be mounted in the work, often inside a tube of suitable size. This pseudoscrew and nut set must mesh as they have been formed upon each other.

# MAKING A SCREW OR BOLT

Round wire or rod is used as the raw material for the screw or bolt shank. In some bolts, the part of the shank just under the head is made *square*, a form that fits into a matching square hole in the metal being joined, thus preventing it from twisting when the nut is turned hard on it in tightening. This idea can be used as a way of fixing a screw or bolt with an ornamental head which must be placed in one particular, immobilized position.

A head can be formed on the shank by immobilizing it in a vise using a strip of leather on both sides to prevent its becoming flattened from the pressure. The head is then formed with a *rivet hammer*, upsetting it with the square peen, then rounding it with the flat peen. It can be shaped further in a half-round depression in a *dapping block* or *rivet block*, and smoothed if necessary with an abrasive paper. The head must be large enough and heavy enough to offer proper resistance to the pressure of its tightened condition to prevent the head from being pulled through the hole. The slot in the head can then be formed by starting the groove with a triangular file to establish its proper position, then changing to a square file to complete it to the required depth.




DIE THREADING AN EXTERNAL THREAD WITH A SCREW PLATE The *screw plate* is a threading die for hand forming external threads on screws and bolts. It consists of a highly tempered tool steel plate pierced with one or more threaded holes, progressively increasing in size, that are circular or double notched for the clearance of metal chips. Screw plates are usually sold with a matching set of *taps*, the tool used to form an internal thread, described below.

When making an external thread, select the screw plate hole whose inner thread diameter is less than the diameter of the shank so that it will cut into the shank and form threads. Clamp the screwhead in a vise with the shank pointing perpendicularly upward. Place the selected screw plate hole flat on the trued shank end, and press the screw plate down hard over the shank to fix it in a starting position. Turn the screw plate handle clockwise and the screw plate grooves will automatically start to cut into the shank as the screw plate advances. Continue to wind the screw plate until the desired depth of thread is formed on the shank, then reverse the direction and unwind the screw plate until it is removed. If the diameter of the shank is too large for the chosen hole, the screw plate may break, or it will stop advancing and if the turning continues the threads already formed will be stripped or worn off. Before this happens, unwind the screw plate and move the shank to the next larger opening in the screw plate, and proceed as before.

DIE THREADING AN EXTERNAL THREAD WITH A CIRCULAR DIE A solid or a two-part circular cutting die can also be used to form the external threads on a screw or bolt. This die is placed in the depression of a two-handled *stock* made to hold dies with the same outer diameter, but with different sized cutting capacities. The stock depression is provided with a shoulder to keep the die from being forced out in use. The stock is also equipped with external set screws that are tightened, and pass through its frame into matching holes in the die perimeter to secure it.

The screw shank with its end filed square and its edge slightly chamfered to ease the start is placed in a vise

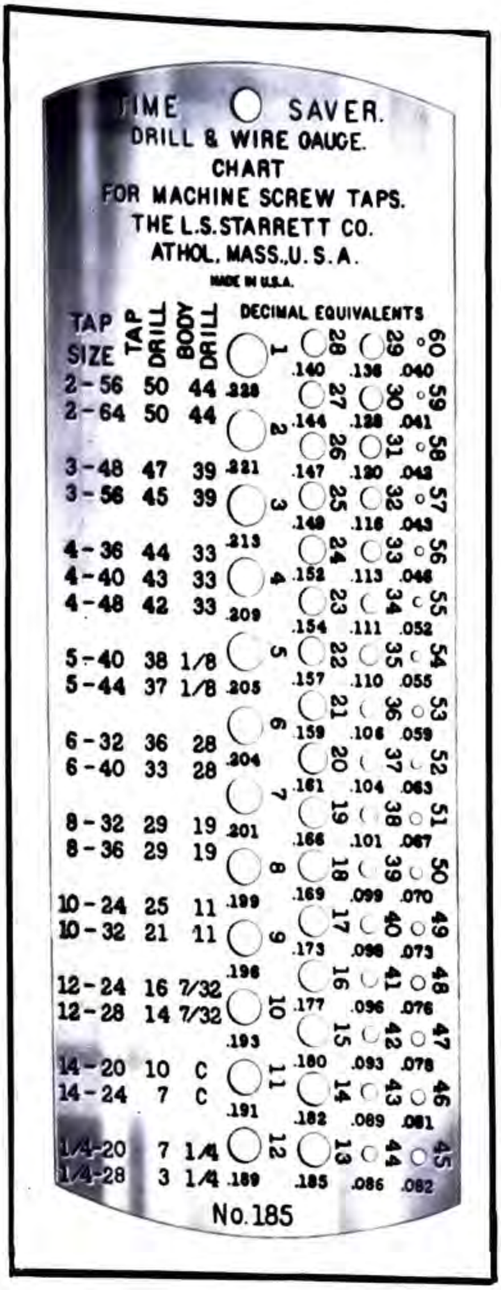
10–36 *DIE THREADING AND TAPPING TOOLS*
1. *Taps* of hard steel in a set of 15 in decreasing sizes from 9/32–1/16 in, to correspond with the hole sizes of the screw plate.
2. *Screw plate* with 14 double-notched holes and 14 single holes, for making small right- and left-hand V-threads.
3. *Circular stock* or round die holder with handles, used for making external threads. In use it rests against the inside shoulder and is screwed tightly in place by five externally mounted set screws surrounding the stock.
4. A *circular, button* or *spring die* used for making external threads on screws up to Ø ½ in. The thread-forming chaser ridges and the metal clearance holes which also provide cutting edges to the die are seen, as well as the outer rim with holes into which the retaining set screws fit.
5. *Tap wrench* with an adjustable lever handle used to hold the square end of taps.
6. *Hand taps*, set of three used when making internal threads of large diameter, and when making blind holes. The first is a starting or *taper tap*, the second an intermediate or *plug tap*, and the third a finishing or *bottoming tap*.
7. A *numbered set of taps and circular dies* for making a matching internal and external thread on a nut and screw respectively. A set screw to hold the die in the stock is at the side.
8. *Goldsmith's taps and circular dies*, a set in 18 sizes with handled stock for each. (*Karl Fischer*)

pointing perpendicularly upward, and the die whose diameter matches or is slightly larger than the core diameter of the shank is pressed down on its trued end. The shank is then lubricated and turned by half turns and partial reverse turns, advancing until the initial threads are properly established by the die's cutting threads. By hand feeding the die progressively on the shank, threads are formed by degrees until the desired thread depth is reached. The stock is then rewound in reverse to remove the die.

FORMING INTERNAL THREADS ON A NUT WITH A HAND TAP To thread a nut for use with a screw or bolt, cut a rectangular piece of sheet metal thick enough to engage a distance of at least three thread crests, otherwise it will not hold on the screw efficiently. Mark its center with a *center punch*. Using a *tap drill* whose number corresponds with the tap size used, drill a hole straight through the center. The drill's diameter should be slightly smaller than or equal to the core diameter of the thread, called tapping size. (Alternately, a hole can be made in the uncut metal, then threaded, and the nut cut out later in any form; an internal thread can also be made at any location on any irregular metal form to hold any part.)

To cut an internal thread, a *hand tap* is used. This is a square-headed, cylindrical or conical hard steel tool having peripheral cutting threads. It is fluted lengthwise to allow for chip clearance and the access of lubricant to the cutting area. Taps are numbered to match the die used to make an external thread. The tap moves forward into the metal with a combined rotary and axial motion, allowing the threads to form in a spiral. The tap is hardened but brittle and easily subject to breakage if unnecessarily forced, therefore it must be handled with care. The tap is held in a solid or an adjustable *tap wrench* which has a central, square opening sized to match the square end of the tap, and is turned by grasping its two handles. Small taps such as those often used by watchmakers and jewelers in combination with a screw plate may be held and turned by inserting their end in a square hole near the handle of a screw plate which then becomes the tap handle.

To make an internal thread in a nut, place the nut flat, clamped in a vise with the tapping hole upright, and place a drop of water-soluble oil in the hole as a lubricant (none needed for brass) to facilitate cutting action. Place the tap, with its handled wrench dead center, upright in the hole. While exerting even pressure on both handles, turn the wrench handle clockwise a quarter turn to work the tap into the hole, then reverse it an eighth turn to break the chips that form which otherwise will resist the tap's advance. Repeat this procedure, gradually advancing through the metal until the tap passes through with its full diameter. When true diameter is reached and the tap turns smoothly and without resistance through the nut, reverse




10–37 *TAP AND DRILL GAUGE*
This shows the correct size tap drill for any common size machine screw tap in National Fine (NF) or National Coarse (NC) Thread Series. The gauge also shows the correct body size drill to use. The 60 holes are marked with the number size and decimal equivalent of the drill that fits each hole. For example: a size 2-56 tap (No. 2 tap with 56 pitch) uses a No. 50 tap drill and a No. 44 body drill. *Photo: Courtesy L. S. Starrett Co.*

## Equivalent Tap Drill, Tap, and Screw Wire Sizes

| Tap Drill Size | | | Tap Sizes | | | Screw Wire Size | |
|---|---|---|---|---|---|---|---|
| Number | Decimal Equivalent Inches | mm | Size No. | Outer Diameter Inches | Root Diameter Inches | Closest Decimal Equivalent Inches | B.&S. Gauge |
| 53 | 0.0595 | 1.512 | 1-64 | 0.0730 | 0.0527 | .0808 | 12 |
| 50 | 0.0700 | 1.778 | 2-56 | 0.0860 | 0.0628 | .0907 | 11 |
| 47 | 0.0785 | 1.994 | 3-48 | 0.0990 | 0.0719 | .1019 | 10 |
| 43 | 0.0890 | 2.235 | 4-40 | 0.1120 | 0.0795 | .1144 | 9 |
| 38 | 0.1015 | 2.578 | 5-40 | 0.1250 | 0.0925 | .1285 | 8 |
| 36 | 0.1065 | 2.705 | 6-32 | 0.1380 | 0.0974 | .1443 | 7 |
| 29 | 0.1360 | 3.454 | 8-32 | 0.1640 | 0.1234 | .1819 | 5 |
| 25 | 0.1495 | 3.802 | 10-24 | 0.1900 | 0.1359 | .2043 | 4 |
| 16 | 0.1770 | 4.498 | 12-24 | 0.2160 | 0.1619 | .2294 | 3 |

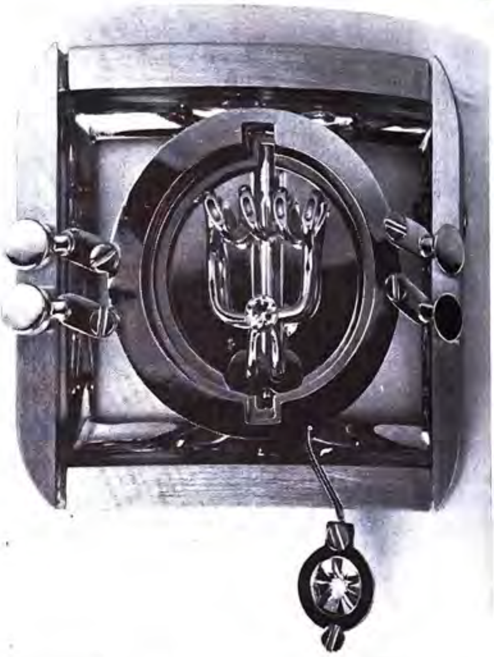
the turning direction to remove the tap. It may be necessary to use a second tap with sharper threads to finish the thread.

TAPPING A BLIND HOLE A *blind hole* is one that does not penetrate the metal. If such a hole is needed, the usual practice is to use three taps, the first a starting or *taper tap*, the second an intermediate or *plug tap*, and the third a finishing or *bottoming tap*, the three comprising a set. (In England they are respectively called taper, second, and plug taps.) The thread-making chaser ridges on each of these are progressively sharper, the first two start with a taper to allow easier entrance, and the last has full threads in its whole length. The distance the tap must penetrate can be controlled and measured with a *depth gauge*, but lacking this, the tap can be marked or a washer can be screwed on the bottoming tap at the correct depth to act as a stop and so avoid breaking through the hole bottom. The procedure is the same as for an ordinary thread, each tap used in its turn.

10–38 PETER SKUBIC, Austria. Finger jewel worn between the fingers, made of stainless steel, silver, and red and blue glass balls. The lathe-turned parts can be moved to adjust size by winding a screw contained within the central tube stem. Height 53 mm. *Photo: Peter Skubic*

10–39 JEM FREYALDENHOVEN, U.S.A. Pin with flat nickel backplate to which the central chased silver unit is held by hidden screws fixed from the back. Flexible nylon spikes protrude from holes. Silver upper left and bottom box shapes are inlaid with diagonal nickel stripes. Black acrylic blocks are filed to make wide black edges around the inlaid and laminated ivory. Height 5 in. *Photo: Jem Freyaldenhoven*

10–40 FRIEDRICH B. MÜLLER, Switzerland. Brooch with red gold cast face, black acrylic back on which a stainless steel plate is screw mounted. On this is a screw-mounted black acrylic panel with light-emitting diodes (LED optical actives) activated by an electronic device powered by three back-mounted batteries. Diodes emit flashes in a sequence of 265 different combinations, the "picture-to-picture" interval approximately half a second. The device is made by André Claude Godet, Thun, Switzerland. *Photo: Mario Tschabold*



10–41 EBERHARD DECHOW, West Germany. Gold brooch with aquamarine. Exposed gold screws are used to hold the central circular unit to the frame and the stone mounting. Width 6.2 cm. *Photo: Günter Meyer, courtesy the Schmuckmuseum, Pforzheim*

10–42 RACHELLE THIEWES LAMBERT, U.S.A. "Pincushion." Steel bracelet with an inner ⅛ in square steel framework soldered to the outer plates to allow parts to be screwed together with cap-headed, unslotted screws. The blue steel patina is obtained with a commercial "gun bluing" solution. The interior is stuffed with fabric and embroidery floss. Size 4½ × 4 × 1½ in. *Photo: Bill Synk*

10–43 POUL HAVGAARD, Denmark, designer; manufacturer Lapponia Jewelry Ltd., Helsinki. "Adam and Eva." Silver ring with a hidden screw below the cast top that permits the interchange of upper spare parts on the ring shaft. *Photo: Winifred Zakowski, courtesy Lapponia Jewelry Ltd.*

# HANDOUTS FROM THE 20TH CENTURY

***(AND BEYOND)***

**A COLLECTION**

OF TEACHING AIDS

GATHERED AND/OR CREATED BY

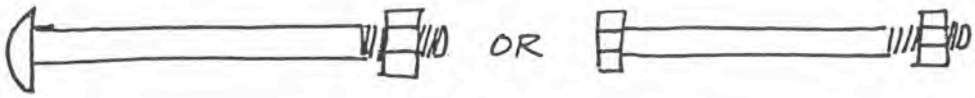
J. FRED WOELL

(OVER A PERIOD OF 30 YEARS)

by J. Fred Woell

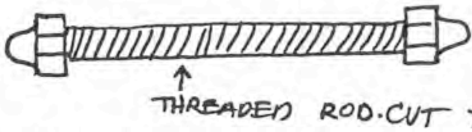
# CONNECTIONS/ mechanical types (ceramic to ceramic and other similar fragile materials):

(1.) INSTEAD OF BOLTS AND NUTS:



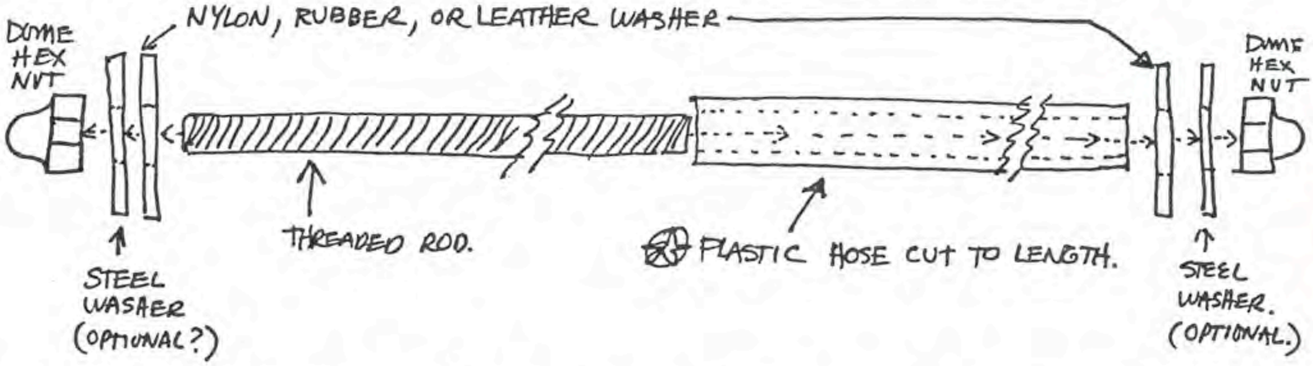

USE DOME HEX NUTS AND THREADED ROD:

DOME HEX NUT: 



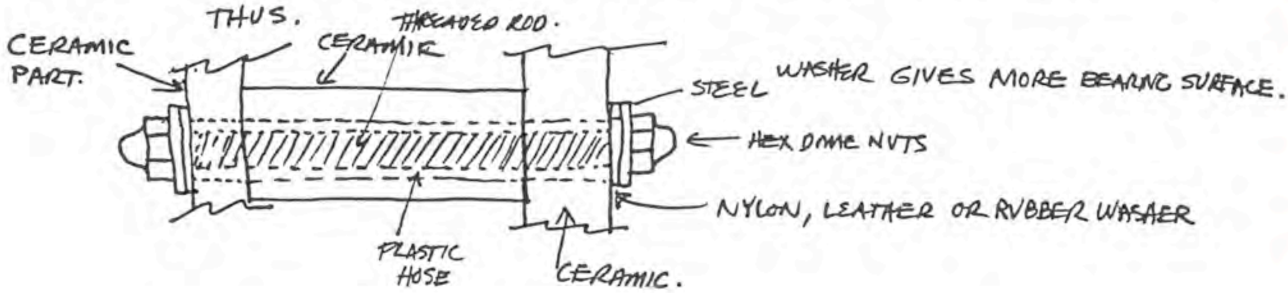

DOME HEX NUTS OR EQUAL WILL GET YOU AWAY FROM BOLT ENDS.

(2.) REGARDING THE PROBLEM OF BOLTS AND NUTS BEARING DIRECTLY UPON FRAGILE CERAMIC SURFACES I SUGGEST FOLLOWING:




✱ PLASTIC HOSE MIGHT BE USED TO ALLOW THREADED ROD TO PASS THROUGH CERAMIC PARTS AND KEEP THIS ROD FROM BREAKING CERAMICS:

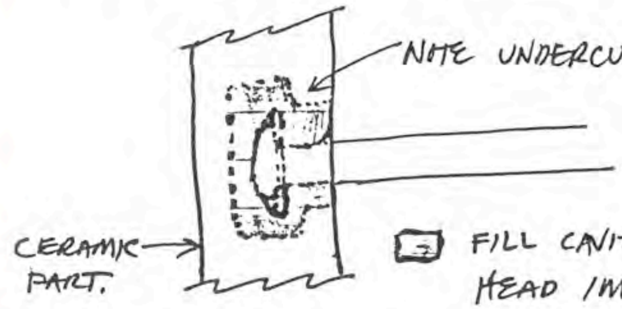
THUS.



OTHER TYPES OF INSULATORS FOR SHOCK PROOFING MOUNTS.

(1.) MAKE YOUR OWN GASKETS, ETC WITH SILICONE ADHESIVES. THEY COME IN COLORS OTHER THAN THE BATHTUB CHALK WHITE- BUY AT LUMBER YARDS OR BUILDING SUPPLIES IN CHALKING GUN SIZES: BLACK, BROWN, CLEAR, ALUMINUM COLORS.

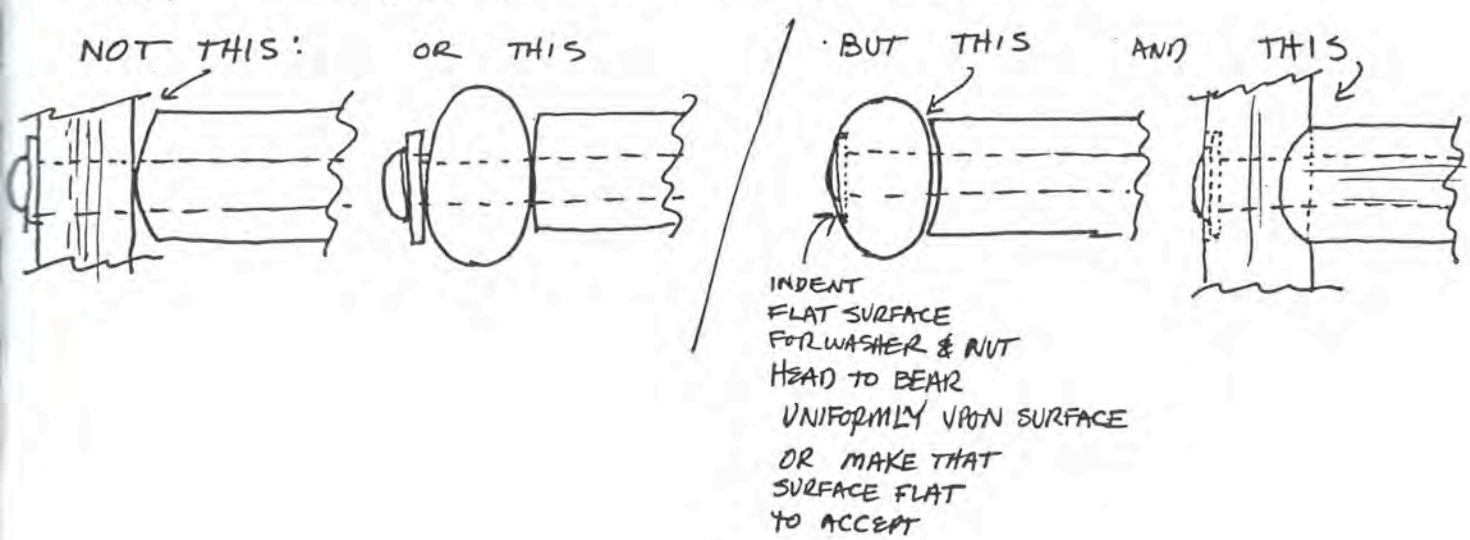
IDEA FOR POSSIBLE HIDDEN MOUNTING SCHEME

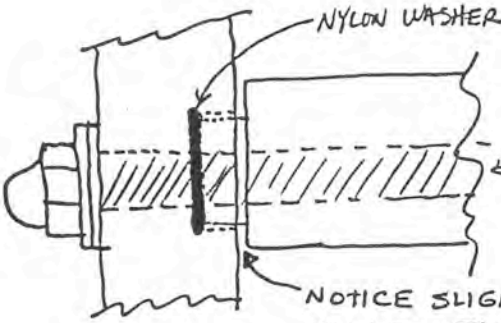



FILL CAVITY WITH SILICONE ADHESIVE WITH BOLT HEAD IMMERSED IN SILICONE ADHESIVE-, ALLOW SILICONE ADHESIVE CURE.

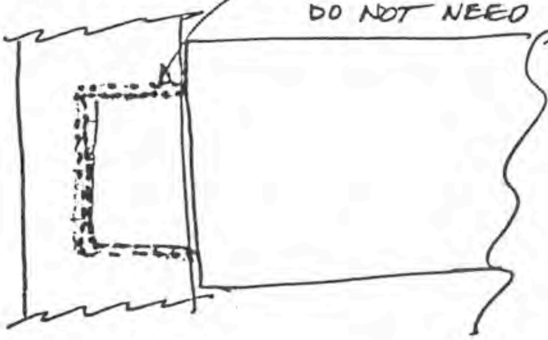
CONNECTION POINTS TO CONSIDER.

1. MAKE SURE PARTS CONFORM TO EACH OTHERS SURFACES - EVEN "KEY" TOGETHER IN SOME CASES. EXAMPLES:



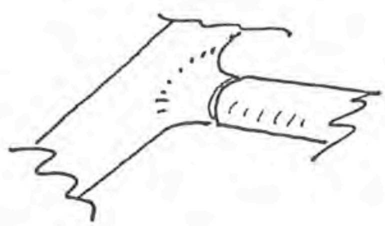



OR JUST.

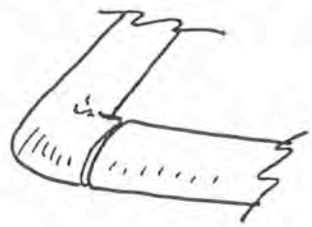



DESIGN CONSIDERATIONS ON JOINING PARTS:

1. MAKE CONNECTING PARTS FLOW INTO EACH OTHER - THUS:

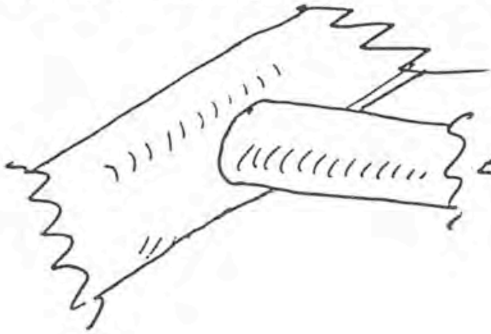


OR

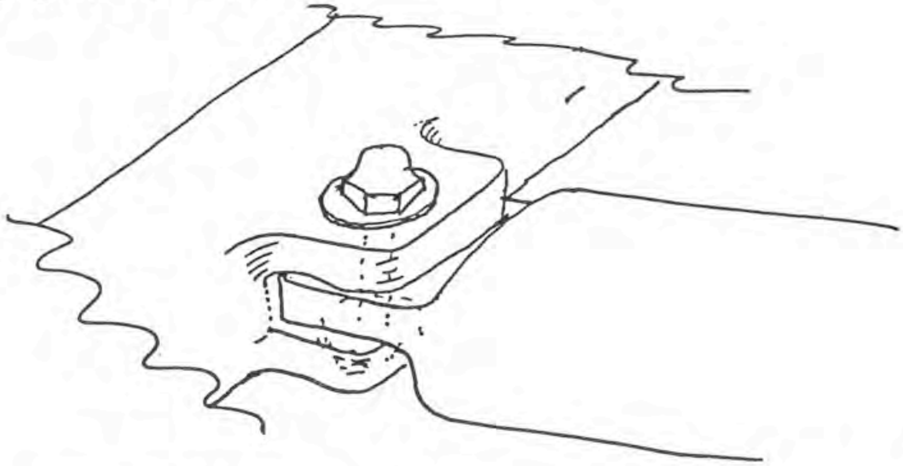


OR

2. MAKE CONNECTING PARTS CONTRAST IN SCALE THUS:



2. MAKE CONNECTING PARTS AND TYPE OF FASTENING DEVICE OBVIOUSLY APART OF THE TOTAL NATURE AND DESIGN OF THE PIECE — THUS:



(I SUGGEST GOING TO A PLACE THAT SELLS OR RENTS SCAFFOLDING- STUDY THE TYPES OF CONNECTORS THEY USE. ALSO MANY MODULAR TYPE UNITS FOR TABLES SHELFS ETC - MIGHT PROVIDE SOME IDEAS)

ANOTHER TYPE: