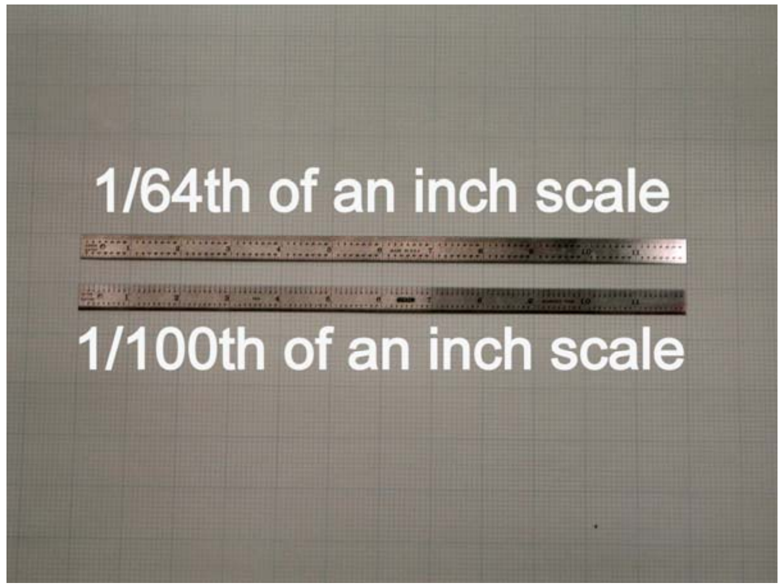
II. METAL FORMING TOOLS

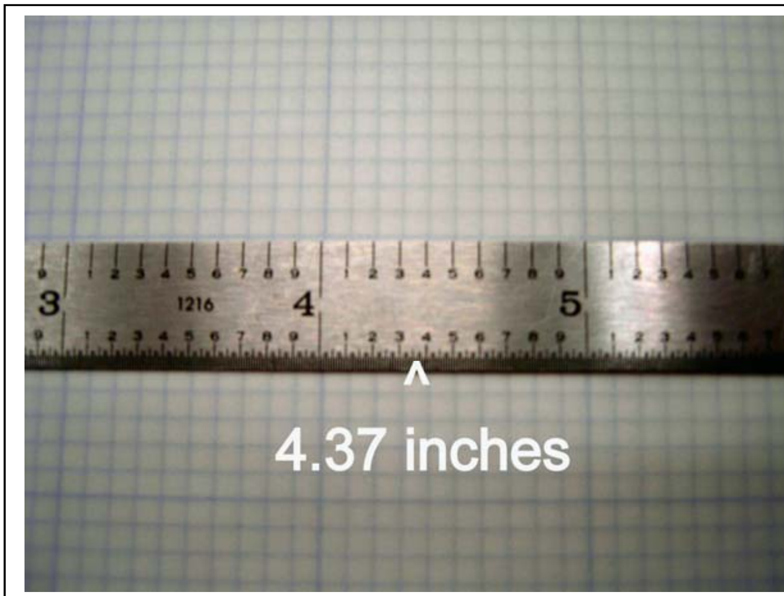
1. Rulers.

    a. Rulers come in all sizes and materials. Short little 6 inch pocket rulers and long 100 foot flexible tape rulers. Rulers come made of plastic, wood, metal, and other materials. However, for the purposes of this course, we will use STEEL rulers with lengths between 6 inches and 18 inches. The standard ruler for this course, unless otherwise specified will be a stainless steel ruler 12 inches long.

    b. The class standard ruler has two sides. One side measures in $^{1}/_{64}$ ths of an inch. The other side measures in $^{1}/_{100}$ ths of an inch. We will use the "metric" english $^{1}/_{100}$ ths of an inch side in this class. Why? Well, tell me quickly how much 3 $^{9}/_{64}$ ths of an inch added to 4 $^{3}/_{16}$ ths of an inch is? Now tell me what 3.14 plus 4.18 inches add up to. Much easier to use "metric" inches, isn't it?

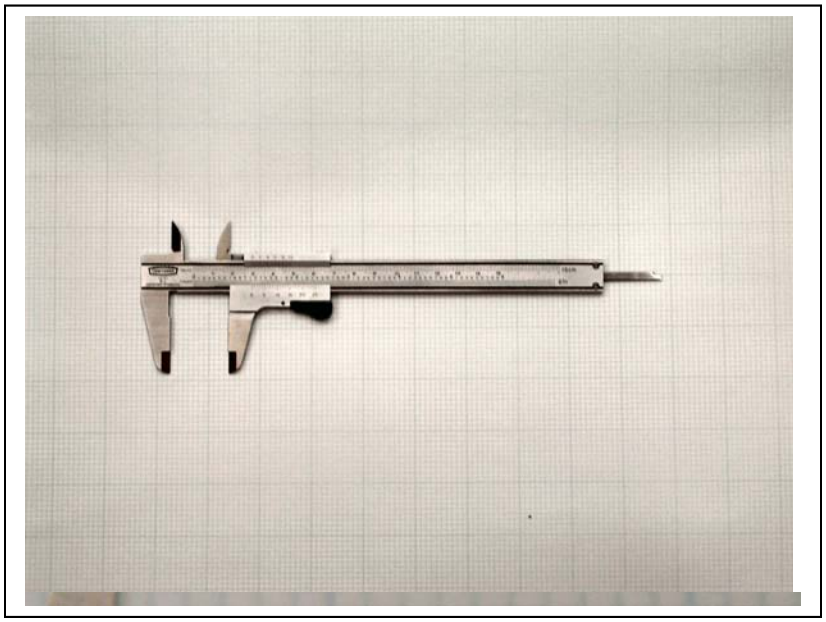


    c. Notice in the photo to the right that the top scale is divided into inches and tenths of inches, while the bottom is divided into inches and hundredths of inches. When we are not too fussy about how long something is to be made, it is far easier to use the tenth-inches side, but if we want something rather accurate, we use the hundredths of an inch side of the ruler. Note that with a ruler like this, the closest you can hope to get something is out in the second decimal place. We call this "ten mil" accuracy because the best you can measure is to ten thousandths of an inch (a "mil" is a thousandth of an inch).



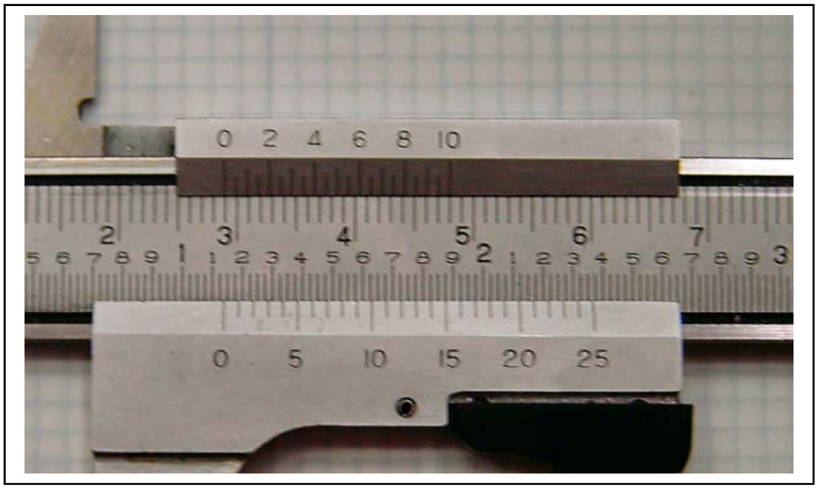
2. Vernier Calipers

   a. When we try for better accuracy than a steel ruler can give us, we turn first to the old tried and true analog vernier caliper. The vernier caliper is capable of giving us accuracy to one-thousandth of an inch (one mil) if properly used.

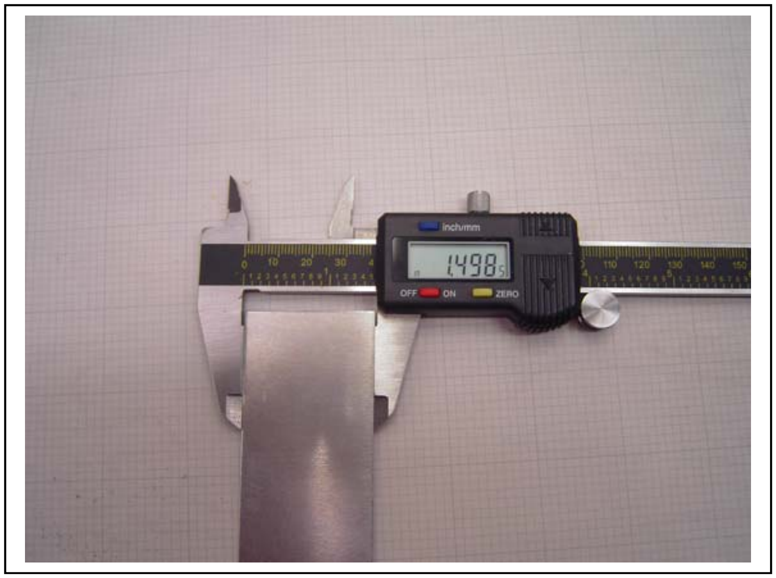


   b. "Properly used" in the preceding paragraph means that the caliper hasn't been used as a hammer or a pry-bar by a previous class so that it's basic accuracy hasn't been compromised. A very accurate "gage block" may be used if there is question about the basic accuracy of the instrument. In addition, you have to be able to properly "interpolate" the last digit for accuracy down to the 1 mil level. A clever arrangement of lines on the scale will allow this interpolation.

   c. Note in the photo to the right on the bottom scale, the 0 (zero) line is somewhere between 1.1 and 1.2 inches. Note also that there are four equally spaced small lines between 1.1 and 1.2 inches. Thus, carving the tenth of an inch up between .1 and .2 inches means each of the small lines is 0.025 of an inch. Note that the 0 line is about halfway between the first and second small line. We therefore might guess that the caliper is set somewhere around 1.135 to 1.140 of an inch. (halfway between 1.125 and 1.150 of an inch). To get that last set of digits down to a mil, note that the bottom scale goes from 0 to 25. Note also that somewhere around 14 on the bottom scale the lines on the bottom scale line up with the lines just above them. We can then say with some confidence that the calipers are measuring (1.125 + 0.014) 1.139 inches.



d. Digital wizardry being what it is, we can eliminate the confusion of this interpolation stuff by means of a digital readout. There is no doubt in my mind that this small aluminum bracket is 1.498 inches wide by 3.996 inches long.



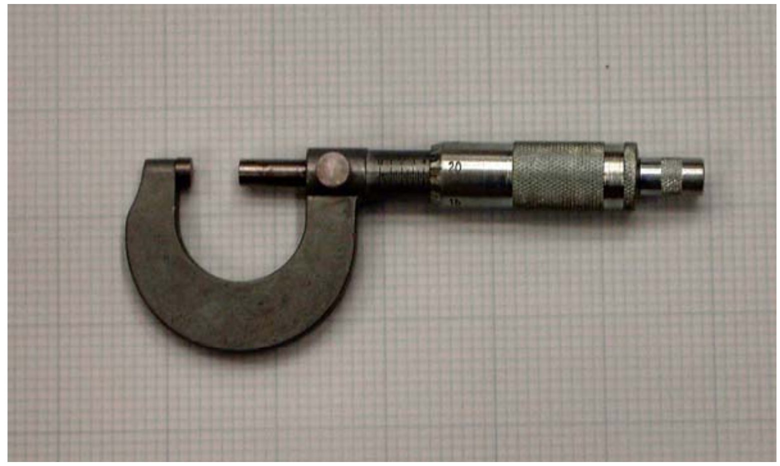
e. Note the controls on the digital caliper in the photo to the right. The red button turns the power on and off (there is an auto-off if the reading doesn't change for a couple of minutes) . The yellow button allows you to zero the reading when the "jaws" are closed. The blue button on the top switches between inches and millimeters. The small round knob to the left of the black readout housing is a roller to move the jaws back and forth. The little knurled knob on the top fastens the jaws in one spot and keeps them from moving.

f. In the photo to the right, you see how ANY caliper or micrometer should be put away. Note that there is an 11 mil gap between the jaws. When you put away a caliper/micrometer, there should be somewhere between ten and fifty mils of gap between the jaws. That way, should the instrument be dropped, the jaws will not "bounce" off one another, bending the jaws, and causing inaccurate readings.

3. Micrometers.

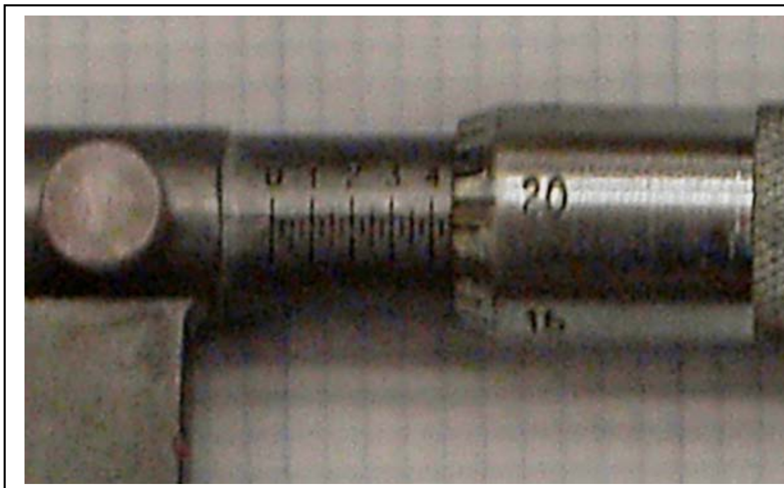
a. A micrometer is nothing more than a caliper that has a rotary thread rather than a straight body. By rotating the thread we can measure the gap between the jaws of the micrometer.

b. The principal parts of a micrometer, on the right, are the frame (c-shaped large part on the left), the barrel (large round part in the center of the picture that doesn't rotate), the thimble (large round part towards the right side that does rotate), the spindle (small round part protruding out the right side of the frame) and the anvil (small little nubbin on the left side of the frame opposite the spindle). The anvil and the spindle together are sometimes called the jaws of the micrometer.



c. Also on the far right side of the picture is the ratchet. The ratchet is used so that the same force is always applied to the part being measured -- it is quite easy to force a micrometer a few thousandths of an inch by applying too much force to the thimble, and the ratchet prevents this.

d. In a similar manner to the caliper above, note that the fixed numbers on the barrel are divided into tenths of an inch, and then each tenth of an inch is divided up into four minor divisions. Each of the minor divisions, then is 0.025 of an inch. Note in the micrometer on the left that the jaws are between 0.4 and 0.5 divisions. Note also that the edge of the thimble is past the first small division, so we know the reading is going to be at least 0.425 inches. Note that the straight line running horizontally down the barrel intercepts the thimble at one division short of 20, or 19. Adding 0.019 to 0.425 gives us a reading of 0.444 inches for the distance between the jaws.



4. Squares

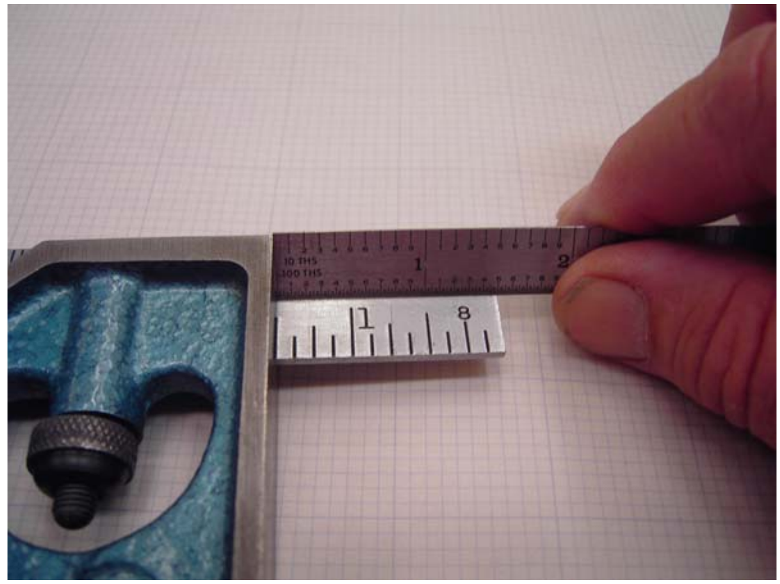
   a. The "combination" square is adjustable in length and gives fairly precise 90° and 45° angle guides. Once again, if a prior class used the combination square as a hammer or a bending bar, the accuracy of the square is not guaranteed

   b. The combination square also includes a bubble level as part of the stock head and is SUPPOSED to have a small pin scriber for marking lines on metal. Most scribers that have been around for a while have long since found their way into a black hole in the universe from which they will never reappear.

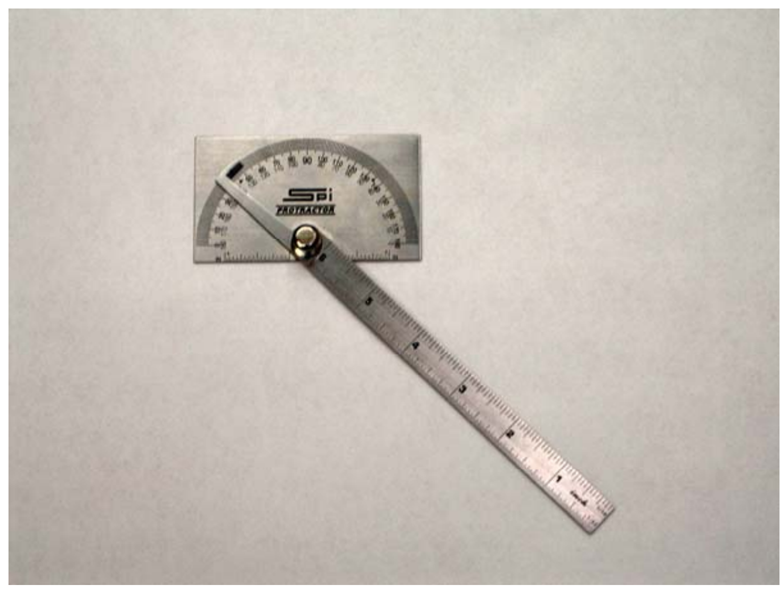
   c. In the photos on the right, we see the combination square. It is comprised of a ruler which has been grooved down the longitudinal axis, a stock head with a knurled knob to fix the head firmly at a spot on the ruler, a bubble level on the left hand side near the bottom of the stock head, and the missing scriber which used to fit into a small hole on the bottom of the stock head.

   d. In the photo on the above right, we can see the stock head set to somewhere around five inches. Note that there are sixteen divisions between four and five inches, so the combination square is out of line with our "metric inch" rule.

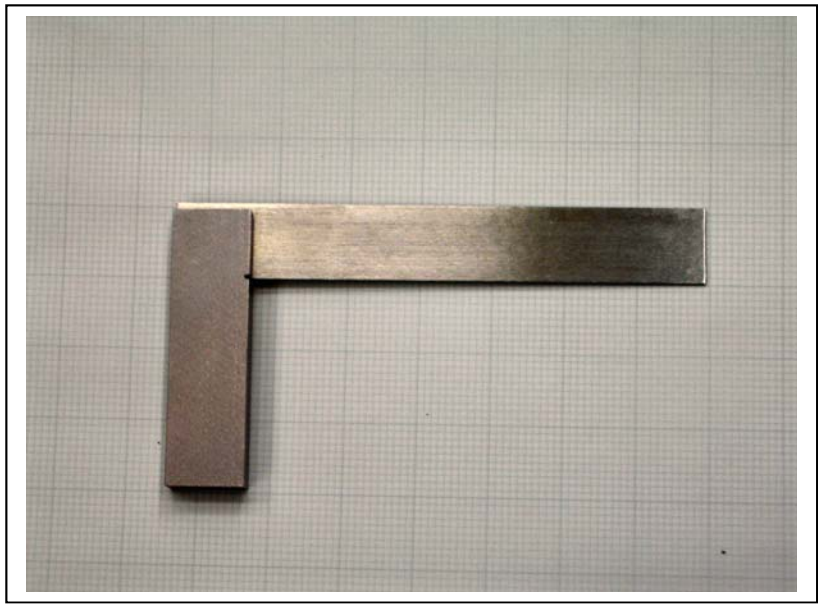
e. The way around that is to set the square with the decimal inch steel ruler for the desired length. You would want to do that anyway, as the square lines are ten to twenty mils thick in and of themselves.



f. There is a "square" whose angle may be varied to any angle you wish. This is called a variable angle square and is quite useful when setting angles for sloped chassis tops, odd cuts on a pc board, and other angles that are not 90° and 45°



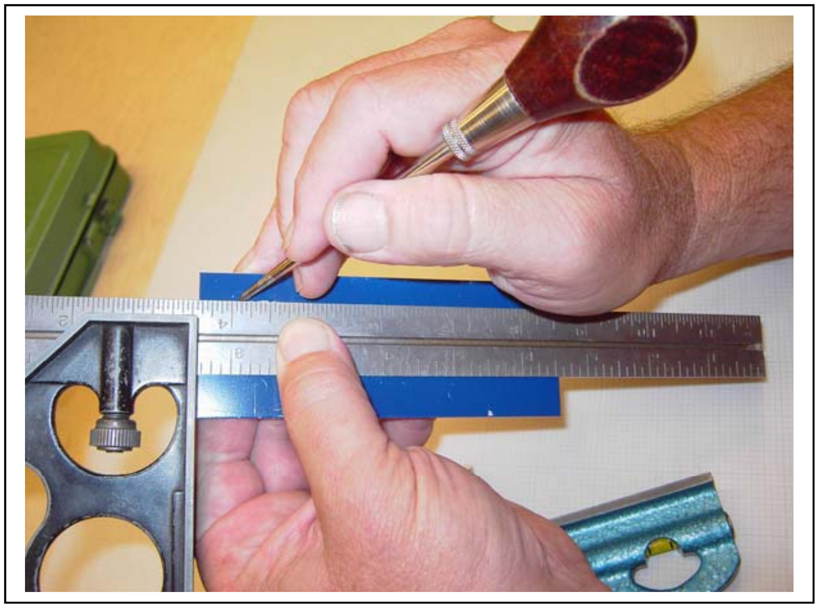
g. The last square in our trilogy is the precision square. This square is not used for layout or other uses that the combination square is capable of doing. This square is rather expensive and is precisely 90°. You use this square to check the other squares for "squareness". Again, it is an expensive piece of equipment and not to be used for anything other than checking other squares.



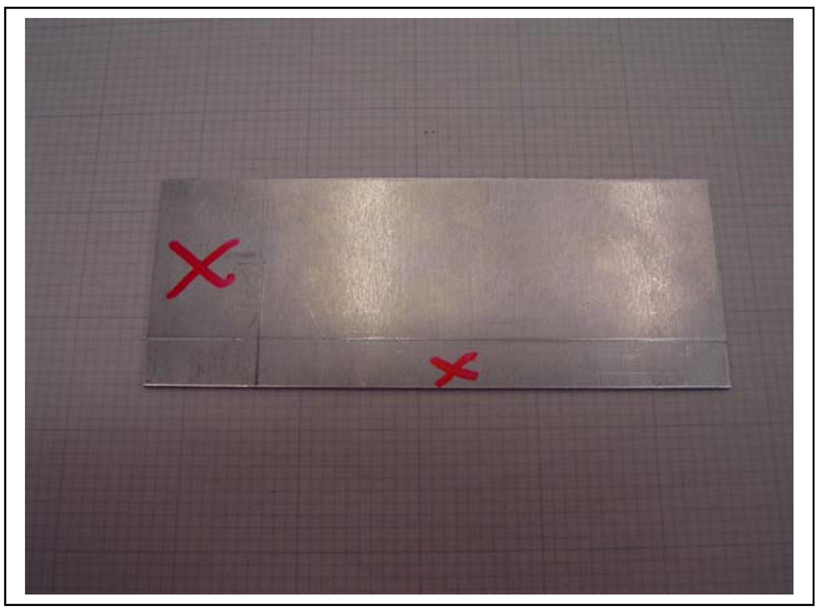
5. Scribes and Center Punches

   a. A scribe is nothing more than a sharp pointed tool that will make a scratch line on metal or paint. The scribe shown here is nothing more than an ice pick that went to college. So long as it has a fairly sharp point on it, practically anything can be used as a scribe. (There have been some times in the field when I needed a scribe and didn't have a "real" one that I used a nail.)

b. If you are doing very precise work and need to keep the surface of the metal as smooth as possible, you can use machinist's bluing on the metal, scribing only through the bluing and not on the aluminum itself. It takes a very steady hand and lots of experience to cut through the bluing without scratching the aluminum.



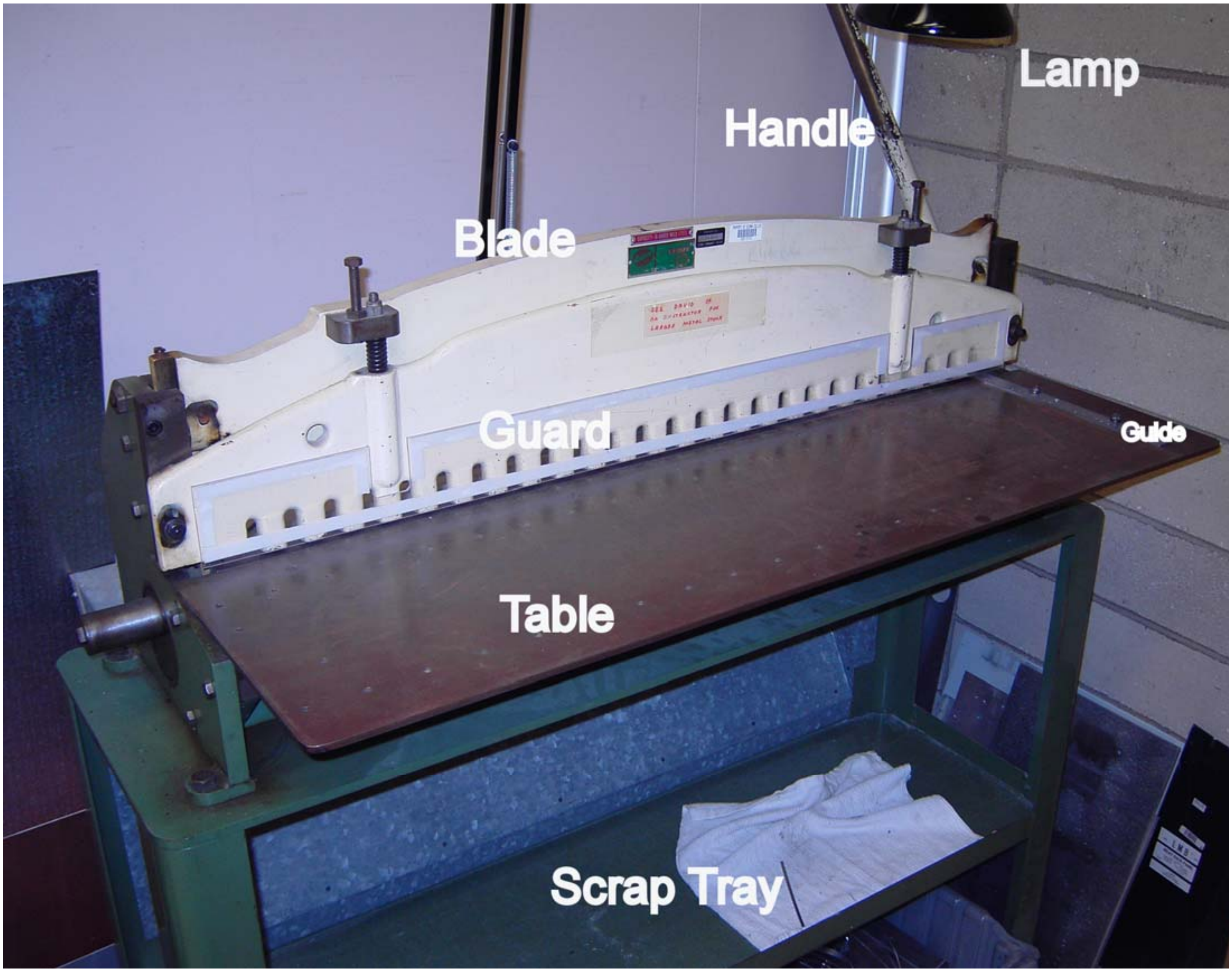
c. For most purposes around the lab or the prototype shop, scratching the cut and drill lines directly onto the aluminum surface itself is the normal way of doing things. Here you see a 2 inch by 5 inch metal plate about to be machined down to the desired size of 1.8 x 4.8 inches. Note the red X marks. These show the part of the plate that will be scrap at the end of the process.



d. A center punch is used to make a dimple in the metal at the exact center of a hole. Shown here is a manual punch that has the sharp point placed exactly where you want the center of the hole and the top (right) end of the punch struck with a hammer. The drill or punch then centers itself in the dimple and makes the hole at that point.

e. When you've got a few dozen holes to center punch on a sheet of metal, the manual punch - hammer routine gets pretty tiring. A spring-loaded center punch makes that job a whole lot easier and is somewhat more accurate than the manual punch. Instead of a sharp blow from a hammer that can drive the manual punch a few mils off center, the automatic punch delivers a precise amount of force directly on target.

6. Shear



a. The shear is the first of the "large" tools that we will discuss. The various parts of the shear are shown above.

b. Once a semester, generally at the beginning, the shear is checked for "square". That is, if the metal to be cut is held tightly against the Guide, is the resultant shear a nearly perfect right angle? If not, the Guide is adjusted until the shear is a right angle. (What tool do we use for checking other tools for right angle?)

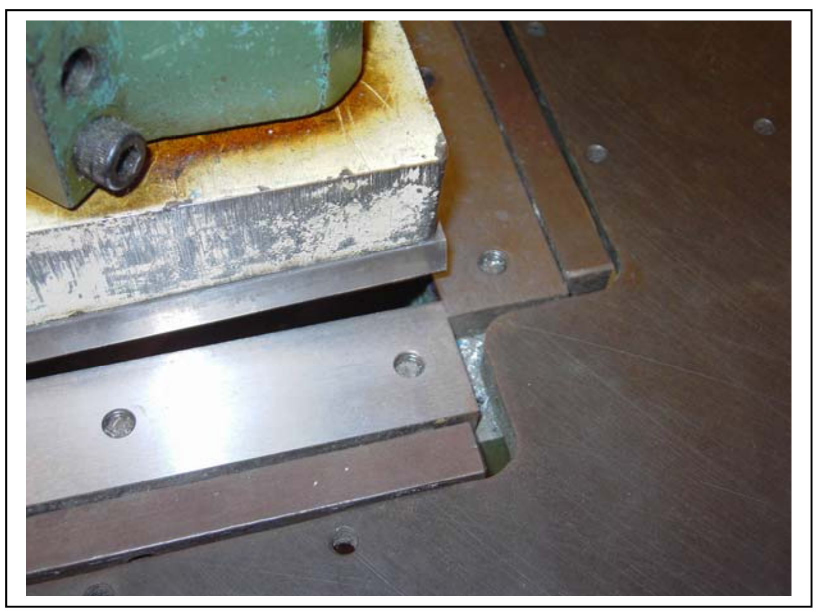
c. The piece to be cut is laid flat on the table and squared up to the guide. Then the piece is slowly inserted underneath the guard until the shear line scribed on the metal lines up with the end of the Guide. That scribe line is incredibly hard to see if the Lamp is not turned on and the person operating the shear is peeking in the gap between the Blade and the Guard. Students who are vertically challenged will find it to their great advantage to locate the OSHA approved step stool that is in the tool room.

d. Once the scribe line is accurately lined up with the end of the Guide, the Handle is slowly brought down to drop both the Guard and the Blade simultaneously. It is very difficult (but not impossible) to get your fingers in a position where they can be sheared off along with the metal. Don't bring the Handle down fast; most people are watching their scribe line and bounce the steel Handle off of their heads.

7. Corner Shear

a. The corner shear is used when you want to take a triangular cut out of metal. Sometimes called a "notch shear" or a "box shear, it is used most often in making chassis where you need a box corner.

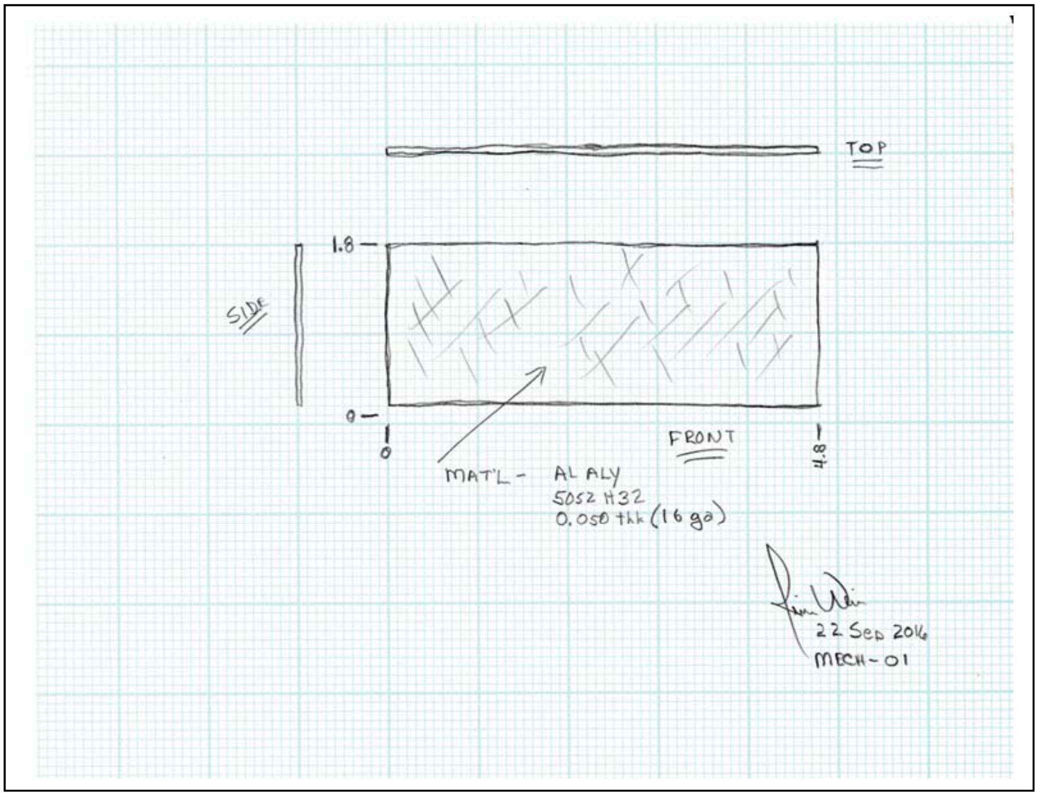
b. In making a box corner, where you want the box to bend up without distortion, it is absolutely mandatory for the metal being cut to be square with the corner shear table. You do this with a combination square lined up with the front or either side of the shear table. CAUTION…we have had more than one combination square cut up when the person doing the cut was more concerned with the cut than whether the square ruler was out of the shear before bringing the handle down



c. Also note that there is NO blade guard on this shear and it is certainly possible to get one or more human appendages partially into the shear.

EXERCISE: Use the steel ruler, combination square, scribe, and shear to make a flat aluminum plate 1.80 x 4.80 inches rectangular. Use the digital vernier calipers to check final size. Use the micrometer to measure the thickness of the metal.

a. Make a paper and pencil rough sketch of the part like so (why do you sign and date it?):



b. **Safety Rule #1. NOBODY goes out of the classroom into the machine shop without safety glasses. Not for tools, not for parts, not for nothing. YOU may not be drilling or grinding, but somebody else may throw a chip directly into your eye from their work.**

c. **Safety Caution #1. While I prefer long pants and closed shoes, if you wear shorts or sandals, be aware while you are working of the possibility of heavy, sharp objects around you.**

d. There is precut aluminum 2" x 5" in the stockroom. Ask the lab tech to get you a piece of this aluminum. Use the precision square to see if the metal you received is square. If it is not, use the shear to square up the metal by taking a small amount off of each of the 2" wide ends.

e. Use the ruler, square, and scribe to scratch lines where you are going to cut the metal.

f. Shear the metal along your scribe lines.

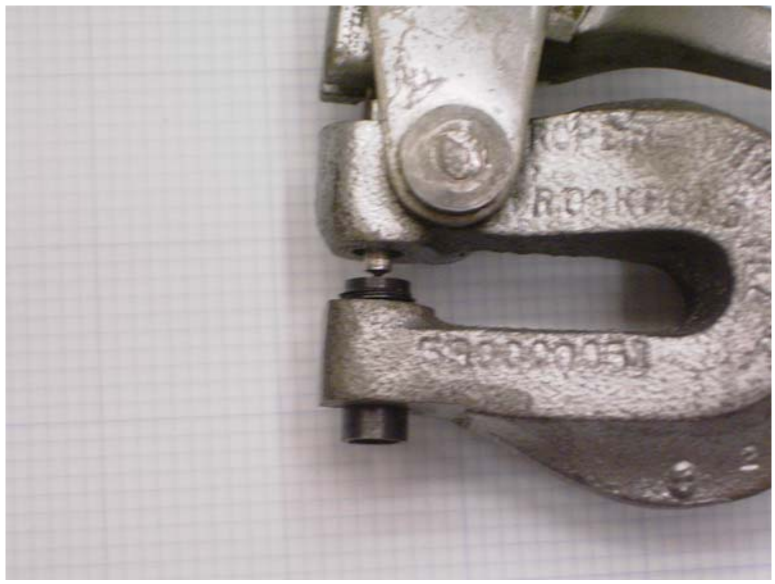
g. Measure the length and width. It should be within 0.020 of the desired value (widths between 1.78 and 1.82; lengths between 4.78 and 4.82). If not, see if you can figure out what you can do to improve the accuracy and cut another piece of metal. Two tries only.

8. Hand Punch

a. The hand-punch (sometimes called a "Roper-Whitney" after the best known manufacturer of hand punches) can punch a very clean burr-free hole in thin sheet metal. In general, we don't try and punch metals thicker than about 50 mils with a R-W punch.

Note that the hole to be punched can be no further away from the edge of the metal than the depth of the "throat" of the frame.

b. The "business end" of a R-W punch. Note the silver punch in the top of the frame and the black die in the bottom of the frame. Each size punch has a corresponding die. When you change punch size you must change to the corresponding die size. While the die is relatively easy to change (it simply threads its way into the frame) the punch is relatively difficult to maneuver the jaws around to change.

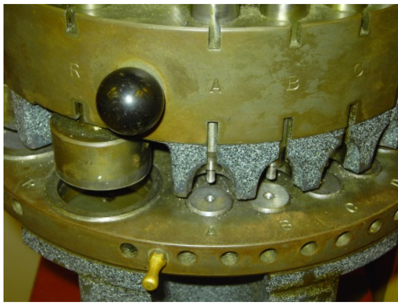
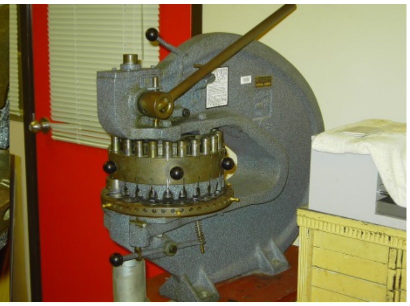


c. A mated pair of punch (right) and die (left). Note the small point on the left end of the punch. This is to locate the center of the hole in the dimple left by the center punch.

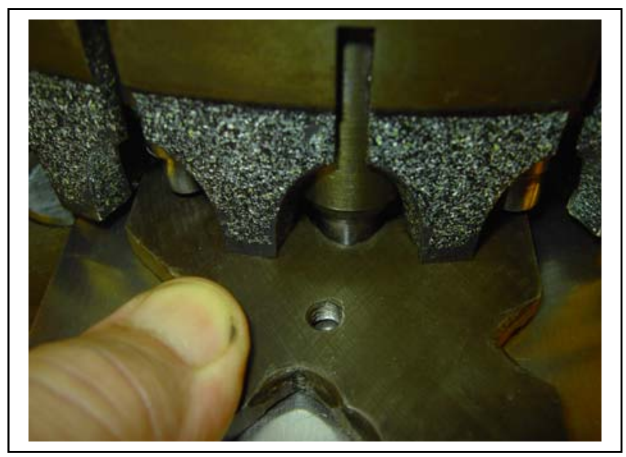
9. Turret Punch

a. A turret punch is similar to the hand punch, in that a punch comes down and forces metal through a sharp die, punching a burr-free hole. However, instead of having to change the punch and die for different size holes, the turret punch contains all the punches and dies on a rotary platform. The turret punch contains sizes from $^{5}/_{32}$ inch to well over 1 ½ inches in diameter.

b. The turret punches, too, have a small point at the end of the punch to accurately locate the dimple from the center punch.

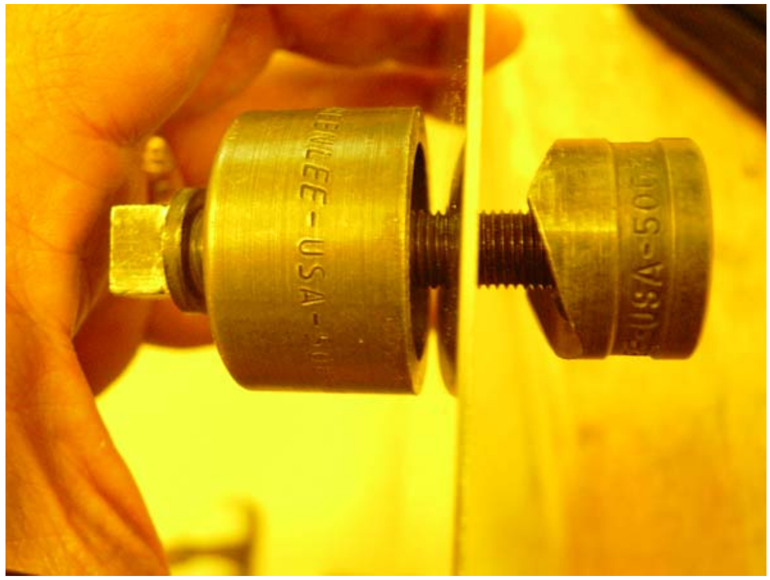
c. When changing hole sizes, one of the critical elements is to make sure that you have the same size punch as you do the die. All the holes are "lettered" from A through R, and it is critical to match up (for instance) a "B" punch with a "B" die.



d. One problem with the turret punch is that it punches so accurate a diameter hole that the metal wants to "come up" with the punch and deforms the sheet. One answer to this is the punch-plate tool. This tool fits around the punch and keeps the metal sheet that you are punching flat.

10. Chassis Punch

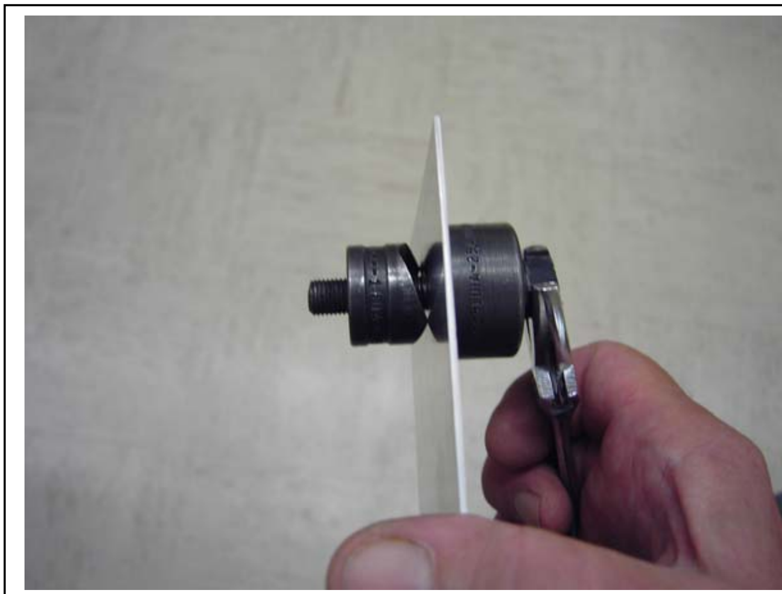
a. A chassis punch (sometimes called a "Greenlee" punch after the most common manufacturer of this punch) comes in three parts. There is the punch (cylinder on the right) the die (the cylinder on the left) and the bolt (the threaded rod going down the center of the punch and die.



b. The advantage to the Greenlee is that you are not constrained on large sheets by the depth of the throat of either the Roper-Whitney or turret punches. With either of these last two punches, you are constrained to holes around the edge that you can reach with the available "reach" of the punch frame.

c. The DISadvantage of a Greenlee is that it requires a good bit of arm strength (especially on large holes) to turn the wrench to bring the punch into the die.

d. The method of use is to drill a hole in the metal sheet exactly where you want the hole and of a diameter exactly equal to the bolt diameter. You then slip the bolt into the die, through the sheet metal, and then thread and tighten the punch onto the bolt. A box or open end wrench is then used to turn the thread and pull the punch into the die.



11. Pliers

a. Generically, pliers are used to get a firm grip on a part that you are maneuvering. They come in many sizes and form factors.

b. Slipjoint pliers ("Channelocks") are so named because one of the jaws slips into a channel in the other jaw to set the opening width of the pliers.

c. Locking pliers ("Vise Grips") come in several different form factors for different purposes.

   The one shown at the right is the generic Vise Grip. There are several permutations of this basic design.

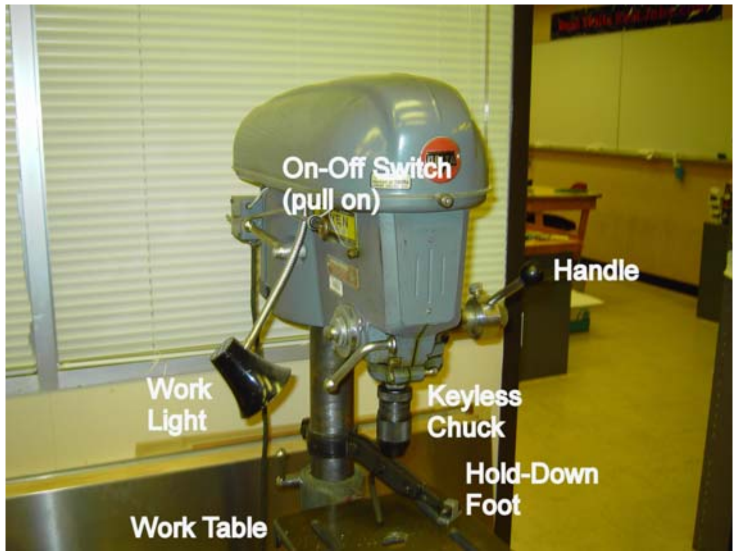
   The one shown at the bottom are what are called "duckbills". The advantage of a duckbill is that you can work with a long straight section of metal and get a straight edge on it if you wish to bend it accurately.

d. "Gas" pliers are what the layman thinks of when you say pliers. Fairly good in a lot of applications, very good in none of them. Very difficult to use them for sheet metal as they tend to mar and scratch the surface of the metal.

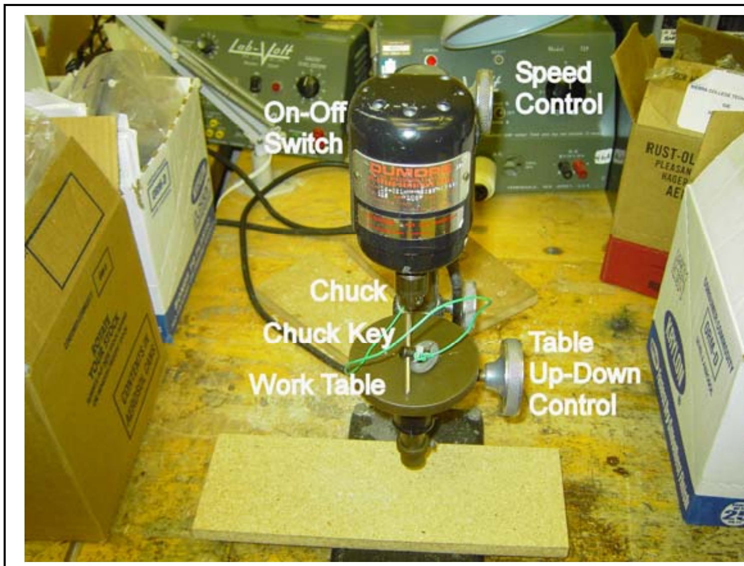
12. Drilling, Reaming, and Nibbling

a. Metal Drill Press. The metal drill press is used with steel bits to drill holes in sheet metal that for whatever reason cannot be punched.

SAFETY -- Some drill presses are fitted with a safety chuck that is a collet and hand-tightened chuck. Others have a metal key to tighten the chuck. That metal key is a flying bullet if it is left in the chuck and the drill press turned on.



b. A smaller but faster turning drill is used for drilling through-holes in pc board material. The faster turning drill will generally give you better holes in pcb material if you use a carbide bit. The down side to that is that carbide bits are expensive. **NOTE** that this drill press uses a keyed chuck and extreme care must be taken to insure that the key is out of the chuck before the drill is turned on.



c. Drill Bits and Standard Sizes. Drill bit diameters come in both fractional sizes (i.e. $^{1}/_{16}$ inch) and numbered/lettered-decimal sizes (i.e. a number 53 -- 0.0635 inches). In general, home workshops work with fractional bits and industry shops work with numbered/lettered. For a lot of "normal" work in an industry shop, here is a table of drills for various screw sizes:

Machine Screws

Dimensions and Other Data

Screw		Threads Per Inch		Clearance Drill*		Tap Drill†			Head					Hex Nut			Washer		
							diameter		round		flat	fillister							
no	dia	coarse	fine	no	dia	no	inches	mm	max OD	max height	max OD	max OD	max height	across flat	across corner	thick-ness	OD	ID	thick-ness
0	0.060	—	80	52	0.064	56	0.047	1.2	0.113	0.053	0.119	0.096	0.059	0.156	0.171	0.046	—	—	—
1	0.073	64	72	47	0.079	53	0.060	1.5	0.138	0.061	0.146	0.118	0.070	0.156	0.171	0.046	—	—	—
2	0.086	56	64	42	0.094	50	0.070	1.8	0.162	0.070	0.172	0.140	0.083	0.187	0.205	0.062	1/4	0.093	0.032
3	0.099	48	—	37	0.104	47	0.079	2.0	0.187	0.078	0.199	0.161	0.095	0.187	0.205	0.062	1/4	0.105	0.020
		—	56			45	0.082	2.1											
4	0.112	40	—	31	0.120	43	0.089	2.3	0.211	0.086	0.225	0.183	0.107	0.250	0.275	0.093	5/16	0.125	0.032
		—	48			42	0.094	2.4											
5	0.125	40	—	29	0.136	38	0.102	2.6	0.236	0.095	0.252	0.205	0.120	0.312	0.344	0.109	3/8	0.140	0.032
		—	44			37	0.104	2.6											
6	0.138	32	—	27	0.144	36	0.107	2.7	0.260	0.103	0.279	0.226	0.132	0.312	0.344	0.109	5/16	0.156	0.026
		—	40			33	0.113	2.9									3/8		0.046
8	0.164	32	—	18	0.170	29	0.136	3.5	0.309	0.119	0.332	0.270	0.156	0.344	0.373	0.125	3/8	0.186	0.032
		—	36			29	0.136	3.5									7/16		0.046
10	0.190	24	—	9	0.196	25	0.150	3.8	0.359	0.136	0.385	0.313	0.180	0.375	0.413	0.125	7/16	0.218	0.036
		—	32			21	0.159	4.0									1/2		0.063
12	0.216	24	—	2	0.221	16	0.177	4.5	0.408	0.152	0.438	0.357	0.205	0.437	0.488	0.156	1/2	0.250	0.063
		—	28			14	0.182	4.6									9/16		
¼	0.250	20	—	—	17/64	7	0.201	5.1	0.472	0.174	0.507	0.414	0.237	0.437	0.488	0.203	9/16	0.281	0.040
		—	28			3	0.213	5.5						0.500	0.577	0.250	5/8		0.063

All dimensions in inches except where noted.
* Clearance-drill sizes are practical values for use of the engineer or technician doing his own shop work.
† Tap-drill sizes are for use in hand tapping material such as brass or soft steel. For copper, aluminum, cast iron, bakelite, or very thin material, the drill should be a size or two larger diameter than shown.

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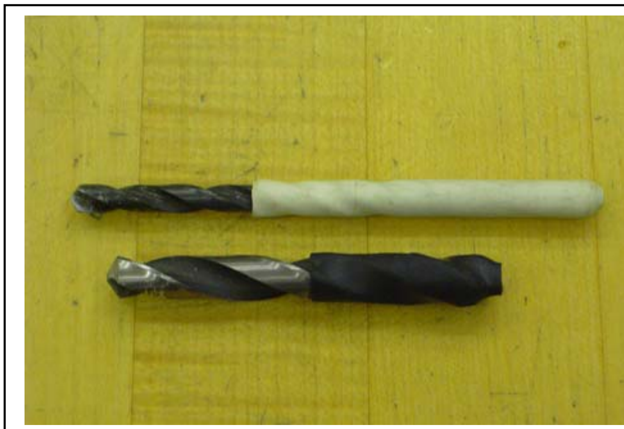
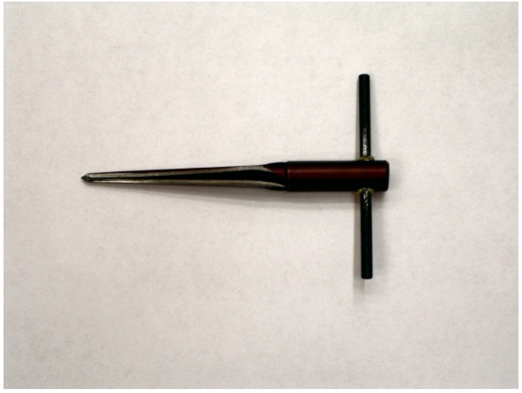
d. Deburring. In general, drilling a hole will create slivers of metal remaining on the part that have been tossed out by the bit. These slivers go by the name of "burrs". A good deburring tool is a large drill bit wrapped with masking tape or shrink sleeving to keep the sharp bit flutes from attacking your hands.



e. When you need to have a hole that is not close to any standard punch or drill size, you can use a T-handled reamer to ream the hole to the exact size you need.

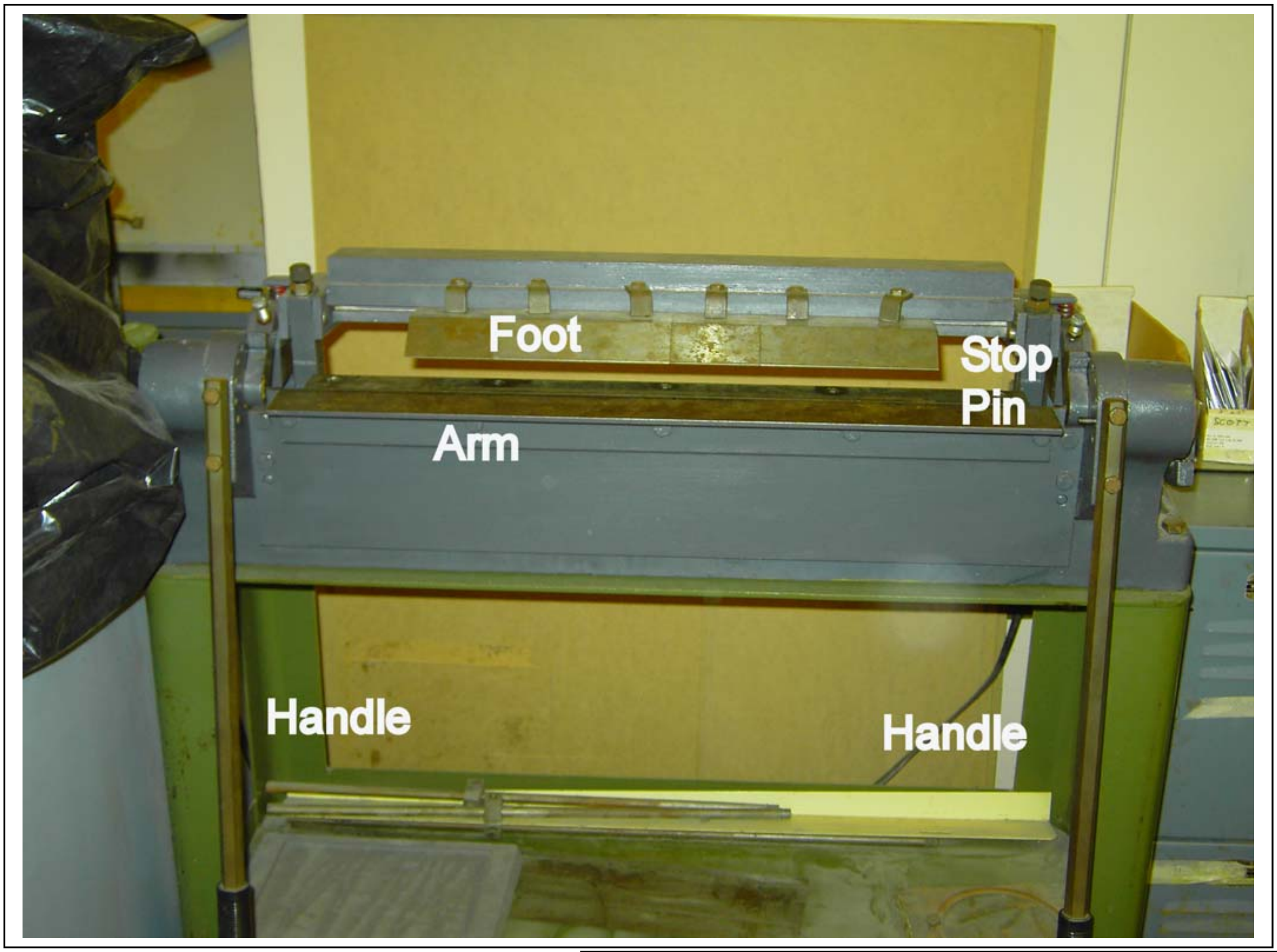


f. When the hole has to be some shape other than round or not the same size as any special punch that you have, you can use the nibbling tool to take rice-grain size pieces out of the metal.

The procedure is to drill a hole slightly larger than the tool diameter on the bottom of the nibbling tool, insert the tool up to the bottom of the tool, then nibble away at the unwanted metal.

13. The Bending Brake

a. The bending brake is used to bend metal at almost any angle that you choose. It consists of the Foot (which holds one side of the metal flat and rigid), the Base (which is what the Foot presses against), the Arm (which is the movable piece that does the bending of the metal), and the Stop Pin (which keeps the brake from overbending the metal).



b. In order to bend a piece of metal without cracking it, you need to set a BEND RADIUS, which allows the metal to have a smooth radius rather than be torn or cracked. The BEND RADIUS is set by how far the Foot is back from the Arm.