U.S.--RADIO MATERIEL SCHOOL, BELLEVUE, D.C.

MECHANICAL PRACTICE.

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NAVAL RESEARCH LABORATORY, BELLEVUE, D. C.

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PREFACE

This pamphlet was originally prepared by Radio Electrician Walter Schimmelpfennig, U. S. N., of the Warrant Officers Radio Engineering School, class No. 13, primarily for use as a text and for reference material in the Radio Matériel School. It should also prove to be of inestimable value as a handbook in the radio workshop.

In the first revision, chapters 3 and 5 were rewritten and chapter 9 added by Radio Electrician Earl R. Schuler, U. S. N., of the Staff, Radio Matériel School.

As with other Radio Matériel School publications, suggestions and criticism are invited.

Commander WALLACE J. MILLER, U. S. N.,
Commanding Officer.

Radio Matériel School,
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CHAPTER 1. SOLDERING—SOLDERING IRONS—TORCHES

SOLDERING

Soldering is the uniting of two or more pieces of metal with a fusible alloy called solder.

The solder must be such that it will melt at a lower temperature than the metals being joined together.

When solder has a melting point close to the melting point of the metals being soldered, a stronger joint results. This is due to the fact that, under these conditions, the metals adhere better.

When a metal is heated, the surface of the metal combines with the oxygen of the air forming an oxide which covers the surface of the metal as a film. This oxide forms more readily and rapidly on some metals than on others, but in all cases prevents the solder from properly fusing with the metal.

Familiar examples of oxide on metals are *rust* on iron and the white deposit visible on aluminum that has been exposed to the atmosphere for some time.

This oxide should always be removed *prior to soldering* by the application of an abrasive to the surfaces to be soldered, or by scraping the surfaces with a knife, file, etc.

When cleansed as above, the metal surfaces are ready to be soldered and the application of the correct flux will prevent their becoming oxidized again before the junction has been made.

FLUXES

Fluxes are of two classes, corrosive and noncorrosive. The corrosive fluxes eat away the soldered metals unless they are thoroughly cleaned off after soldering. Corrosive fluxes are seldom used in electrical work as there is a possibility of some flux remaining on the joint and eventually opening the circuit by eating through the metal. They also lower the insulation resistance of the circuits and increase electrical leakage since all types of corrosive flux are excellent conductors.

Zinc chloride and *sal-ammoniac* are corrosive fluxes.

Rosin is a noncorrosive flux and is most commonly used in electrical work. It may be obtained in powdered, liquid, or paste form.

Different metals solder better with different fluxes.

For delicate electrical or radio work we employ a flux whose residue is a poor conductor of electrical current, which is noncorrosive, and which will have no tendency to collect moisture, dust, or other foreign matter. The collection of moisture and dirt about electrical circuits greatly lowers the insulation resistance and increases current leakage.

Rosin, being a poor conductor, noncorrosive, and its residue having no tendency to gather moisture, dust, or foreign matter (except when used in the paste form), is the best and safest electrical flux available.

Rosin is disintegrated with heat, so its active fluxing life is limited by the length of time and the temperature to which it is subjected in the soldering operation.

When using rosin cored solder, remember that the rosin *must* come in actual contact with the joint to be soldered. It will then be able to dissolve the oxides and float them from the surface to be soldered.

Paste fluxes contain grease to counteract corrosion, but it has been found that, where a flux containing a corrosive acid has been used, the presence of this grease will not prevent corrosion, for corrosive action will take place beneath the film of grease.

Also, the greasy residue of paste fluxes is a collector of dirt, which is not a desirable feature.

The usual fluxes for common metals are:

Brass, copper, tin	Rosin.
Lead	Tallow, rosin, or stearine.
Iron, steel	Borax or sal-ammoniac.
Galvanized iron	Zinc chloride.
Zinc	Zinc chloride.
Aluminum	Stearine.

Stearic acid or "stearine" may be used in soldering aluminum, but a special aluminum solder is now available which makes the use of flux unnecessary.

SOLDERS

There are two general classes of solders: *Hard* and *soft*.

Hard Solder.

Hard solder fuses at red heat, soft solder fuses at a comparatively low temperature.

Hard solders are made from combinations of silver, copper, zinc, and gold. They find their chief use in brazing or hard soldering, the operations being closely allied.

In joining such metals as brass, german silver, gun metal, etc., hard solder is used. A strong joint is assured by its use and in color matches that of the metal involved to some extent.

A soldering iron cannot be used as a source of heat in the case of hard soldering, a blow torch, acetylene torch, or other device capable of delivering intense pointed heat being required.

Soft Solder.

Soft solders are made chiefly of tin and lead. They are used for electrical work and general soldering where the mechanical strain is small.

"Common," "medium," and "fine" are the terms applied to various soft solders according to their tin content. The ones containing the highest percentage of lead are the cheapest and have the highest melting temperature.

"Fine" and "medium" are used in electrical work. The "common" is used in plumbing and splicing the covering of lead-covered cables.

The mechanical strength of soft solder is low.

SOLDERING APPLIANCES AND PRACTICE—ELECTRIC SOLDERING IRON AND COPPER

Soldering coppers, heated by means of blow torches or gasoline fire-pots, are used mainly in metal working and plumbing and will prove useful to a naval radioman only when an electric soldering iron is not available or for soldering heavy galvalnized iron.

The term "soldering iron" as used below will apply to both the electric iron and the soldering copper. Specific mention of either will be made where necessary.

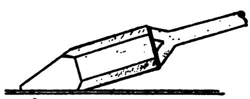


FIGURE 1.—The correct method of applying the point to the work. Maximum heat transfer to the work is assured.

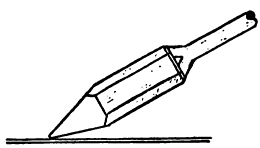


FIGURE 2.—The incorrect method of application. Slow work and poor joints will result from this method.

The heat concentration point of the soldering iron (the copper tip) should be sufficiently large in comparison with the metallic pieces to be soldered so as to insure a good junction.

"Rosin joints," insecurely soldered connections, and slowness of production are often due to an undersized soldering tool.

When metal surfaces to be joined have absorbed enough heat to melt solder freely, *then and only then* can we secure a properly soldered connection.

Failure to secure a temperature suitable for soldering is often due to lack of heat conducting surface in the heat transmitting devices, or carelessness on the part of the operator in neglecting to properly apply the conducting surface to the work.

An undersized iron will not deliver enough heat to allow for heat dissipation throughout an oversized metallic surface and to produce a good junction also.

Where a vise, metal clamp, or similar metallic device is used to hold metals while soldering, wooden slabs, or slabs of other nonconductors of heat, should be inserted between the metallic jaws of the holding device and the metal being soldered. This procedure will enable more effective and rapid soldering by preventing transfer of heat to the holding device.

By inserting two wooden strips between the jaws of a vise and clamping the shank or handle of the soldering iron between them, the operator's hands will be free to apply the solder and handle the work as desired.

An improperly shaped point is another cause of insufficient delivery of heat for soldering.

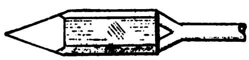


FIGURE 3.—A correctly shaped point. The point is blunt in comparison with that of fig. 4, and it can deliver its heat rapidly enough to overcome radiation in the work.

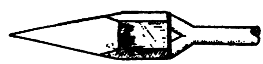


FIGURE 4.—The point is long and slender and will be unable to compensate for radiation in work. However, this point will prove suitable for smaller work where radiation of heat is not great.

An overheated iron should be avoided. Not only will such an iron not solder well, but its life will be shortened by overheating. Pitting and tarnishing of the copper tip are other evils of overheating.

Overheating may be recognized by rapid tarnishing of the copper tip's tinned surface.

To prevent overheating an electric soldering iron it should be disconnected when it is not to be used for some time. This results in time being wasted in waiting for it to heat unless it is connected again for some time before it is needed.

To allow irons to be maintained at soldering heat and still not overheat in use, two methods are in use in the Radio Matériel School:

(*a*) A metallic, flanged rack in which the iron is placed between the short periods of use. This rack provides sufficient additional radiation surface to prevent iron overheating.

(*b*) A snap switch resistance arrangement whereby the resistance may be connected in series with the iron when "standing-by." A schematic diagram of this arrangement is shown in figure 5.

With the resistance in series, the iron is hot enough to do light soldering and still is prevented from overheating.

In an emergency, where the heating element of an electric iron is burnt out, the copper tip may be heated by means of a torch.

In soldering, one face (or part of one face) of the tinned tip should be applied to the metals to be soldered until the metals are heated sufficiently to melt the solder. This is called "sweating."

A good junction will never be obtained where the metals are not heated to the melting temperature of the solder used.

Applying the solder to the hot tip and allowing it to drip or run onto the junction point should *never* be done.

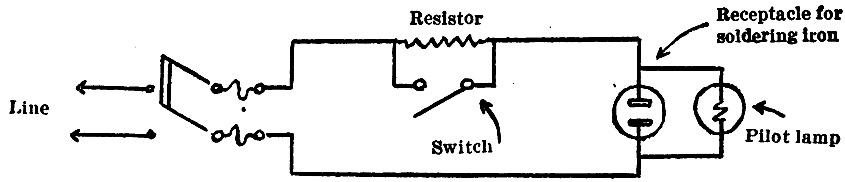


FIGURE 5.

Should it be desired to use an iron in a cramped space where solder might be transferred from one of the soldering faces not in use to places not desired, the tinning of but one face of the point will confine the solder to desired areas.

Do not apply solder and flux to the iron.

Apply it directly to the joint to be soldered after the metallic pieces in the joint have attained the temperature that will melt the solder.

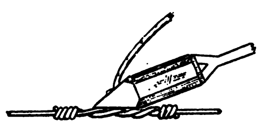


FIGURE 6.—The incorrect method of applying cored solder. The rosin flux does not reach the area of the joint and a faulty junction results.

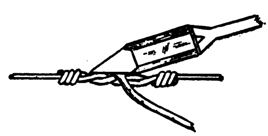


FIGURE 7.—The correct method of applying cored solder. To accomplish a securely soldered joint, the best and easiest way is to apply the solder directly to the heated surfaces of the joint.

The best soldering practice demands that we refrain from applying flame directly to the surface to be soldered.

Flame is apt to produce excessive oxidation or carbonization of the surface, and rosin, particularly, is too mild to dissolve a heavy film of either.

The practice of operators holding one part of the work in their hands while joining it to another part is a very bad one. The fault lies in their inability to hold the part steady at the critical period when the solder passes from its fluid stage to hardness. The slightest tremor at that moment will result in a partially fractured joint which may not manifest weakness at once but may give way under strain later on.

When practicable, clamps or other holding devices should be used to hold all pieces of the work steady and in place for soldering.

When we consider thermal conductivity, copper heads the list of commercial mètals. This makes copper a comparatively difficult metal to solder when a large area is involved.

With two pieces of copper and two pices of steel of identical weight and shape, it takes considerably more heat to maintain solder at the melting temperature at a localized spot on copper than it does on steel. This is because steel is a relatively poor conductor of heat.

Figure 8 illustrates a type of copper which is desirable for seam soldering on sheet metal. A copper of this shape provides a method

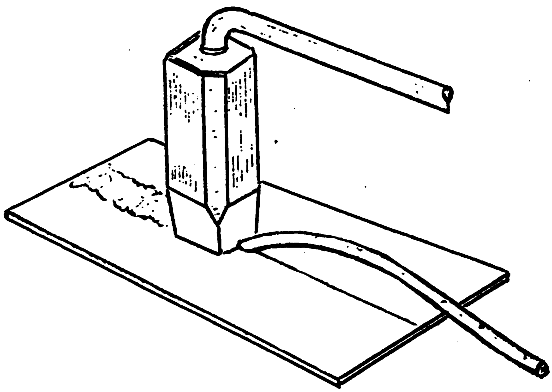


FIGURE 8.

whereby the operator may apply rosin-cored solder in advance of the iron travel at the junction of the seam and the copper. This will permit the flux to penetrate the recess of the seam and the solder will flow as the iron passes over the surface.

The operator should draw the iron slowly and steadily toward himself, applying small amounts of solder as he progresses. This method assures a smooth, uniform, and continuous solder bond.

Extremely deep seams requiring sweating are most easily made by a previous tinning of the soldering surfaces of the metal before making the seam.

The soldering of a tip to a telephone cord presents a difficult soldering problem when not done correctly.

The cord comprises many copper-cotton threads wrapped in various outer coverings.

The outer covering is removed at the cord end and the copper-cotton threads made bare over a length equal to about three-fourths depth of the cup.

A strand of about No. 40 copper wire, or a strand of lamp cord, about 6 inches in length is cleaned and then tinned by applying heat to it and drawing it through a small pool of molten solder.

This tinned strand is then used to bind the copper-cotton threads together in the same manner as the end of a hemp line is "whipped".

With the binding complete, a soldering iron and a small amount of rosin cored solder is applied, and a smooth, strong, and tight fitting sleeve about the copper-cotton thread results.

The tip cup is then filled with molten solder by applying a soldering iron to the outside surface of the cup and feeding solder in at the top. (Telephone tips are tinned by the manufacturer, so the cups need not be emptied to inspect tinning as in the case of lugs.)

When filled, the cord end is inserted in the tip cup as far as it will go, the iron is immediately removed from the cup surface, and the tip allowed to cool.

Care should be taken to insure the removal of the iron before the heat becomes sufficient to burn the cotton threads of the cord, for such burning weakens the cord structure and necessitates beginning the task all over again.

Lizendraht (litz) wire differs from telephone cord in that each strand is solid copper and is coated with insulating enamel. No cotton thread is interwoven with the metal conductor.

The insulating enamel must be removed before soldering can be effective.

Two methods may be used to remove "litz" enamel, one (*b*) requiring more care than the other:

(*a*) With the outer insulation removed, twist the enameled strands tightly together, place twisted strands in the flame of a torch until they become nearly red hot, then quickly remove and dip in alcohol. (Water may be used but is not as effective.) The enamel may then be removed by wiping the strands.

(*b*) With outer insulation removed, fan the strands and hold them in the flame of a torch for about a second (depending on the size of the strands). Remove before a red heat is attained and immediately dip the strands in alcohol. Wiping will then remove the enamel.

The last method removes the enamel more thoroughly than the first.

Care should be taken to avoid overheating the strands lest they melt.

Be prepared to smother the alcohol container should the alcohol ignite when dipping the hot strands into it. A piece of metal laid over the container opening is an effective means of smothering. *Do not try to blow out the flame.*

To Tin a Soldering Iron.

1. Heat the iron.
2. File the faces of the point bright for a distance of ½ to ¾ inch.
3. Place a piece of rosin-cored solder upon a piece of tin. Or, for irons heated by flame, place a small amount of powdered rosin mixed with sal-ammoniac and a small lump of solder upon a piece of tin.
4. With the temperature of the iron such that it readily melts solder, rub the cleaned faces of the point in the molten mixture of solder and flux until the solder adheres to the faces and imparts the color of tin to them.
5. Wipe off the faces of the iron with a clean damp rag.

To Repair a Burned-Out Soldering Iron.

1. Remove the ruptured heating element, carefully noting how the entering wires and the windings are arranged.
2. If the removed wire is of the circular variety, ascertain its size with a wire gauge: if of the flat variety, determine its square mil area by means of a micrometer.
3. Ascertain the amount of removed resistance wire by measuring the length of same or by counting the turns, the former being preferable.
4. Discard any broken mica or worn asbestos which may be in evidence.
5. Procure identical wire to that removed for rewinding (or as nearly identical as possible).

This will usually be found to be some variety of nichrome (nickel-chromium) wire, which is especially adapted to high temperatures.

There are three types of resistance wire in use by the Navy. Use the type designed for heating elements. The other types will not last long in high temperature operation.

A difference between the wire removed and that used to replace it of one size larger or smaller is about the maximum allowable.

If one size smaller is used, the length of wire should be somewhat less to give about the same resistance. If one size larger, somewhat more for the same reason.

6. Procure a good grade of mica and asbestos for any needed replacements.
7. Secure one end of new wire in a vise or clamp.
8. With the iron in one hand, grasp the free end of the new wire in the other hand and stretch the wire taut. Wind the coil, keeping the wire taut.
9. Double back and twist together sufficient resistance wire near the two ends to form leads. This doubling back adds mechanical strength where needed.

10. Avoid sharp turns and kinks in the resistance wire in bringing its ends through the asbestos sleeves, beads, or other channels between the winding and the binding posts inside the handle.

An occasional iron will be found having no binding posts inside the handle for connecting the copper wire cord to the resistance wire. In such a case, remove the oxide coating from the resistance wire and twist or braid the copper and resistance wires together for about 6 inches, beginning where the resistance wire leaves the spool and braid towards the handle.

Simply knotting the copper and resistance wires together to connect them will produce a high resistance joint which will not last due to the excessive temperature which will result at that point.

Assemble the iron and test it.

TORCHES

To Prepare a Blow Torch for Use.

1. See that there is enough gasoline in torch to complete the work.
2. Open the valve at the bottom of the air pump (if the torch has such a valve) and pump air into the tank until pumping becomes a bit difficult. Care should be taken to insure that the internal air pressure is not made excessive. Torch bottoms have been known to rupture because of excessive pumping of air into the tank.
3. Close the valve at the bottom of the pump. This rids the pump of back pressure from the tank.
4. Place the torch where no wind will strike it and where there is no danger of fire.
5. Blocking the mouth of the torch tube with a small block of wood or like impediment, open the needle valve in the jet and allow the trough under the torch tube to fill with gasoline.
6. When the trough has filled, close the jet valve and remove the tube impediment.
7. Light the gasoline in the trough and see that the flame strikes the torch tube directly above rather than being deflected to one side by the wind.
8. When the gasoline in the trough is nearly expended, open the needle valve and permit the gasoline vapor which issues from the jet to ignite.
9. When the flame from the trough burns out, the torch flame should become blue and burn with considerable force.
10. Should the torch flame fail to become blue, insufficient heating of the tube would be indicated. In this case, direct the torch flame against a noninflammable surface (such as a steel plate) in such a manner that the heat therefrom will be reflected upon the torch tube.

This will soon cause the jet to heat sufficiently to produce a blue flame.

The hook and Y fittings on top of the torch tube are to support a soldering copper while it is being heated by the torch flame.

In soldering large lugs and other large metallic devices, it is usually best to apply the heat directly from the torch to the metal involved (but not to the surface to be soldered) instead of through the medium of a soldering copper. By this method more thorough and rapid heating of the metal is assured.

When through using a torch, the jet valve should be closed to extinguish the flame and then slightly reopened (about one-quarter turn) to prevent the valve stem from "freezing" after the torch has cooled off.

Alcohol Torches.

There are two principal types of *alcohol blow torches:* the mouth-operated type and the tank-operated type.

The mouth-operated type comprises an alcohol tank capable of holding about one half pint of alcohol, a wick which feeds alcohol from said tank to supply the necessary flame beneath the air jet, a rubber tube attachment, the air jet, and a wick cap.

The removal of a hexagonal nut gives access to the tank for filling with alcohol and renewing the wick when needed.

With alcohol in the tank, the wick cap is removed from atop the wick pipe and the wick is lighted.

With the wick lighted, the free end of the rubber tube is placed in the operator's mouth and air is blown through the jet.

The air converges to a fine point where it emerges from the jet and blows the wick flame at right angles to its normal plane.

A sharp pointed flame results which is suitable for soldering lugs, etc., and even light silver-soldering.

The flame does not stand up well in a breeze because the wick flame is easily extinguished.

Precautions.—Place wick cap over top of wick pipe when torch is not in use. This prevents evaporation of the alcohol.

The tank-operated blow torch greatly resembles the gasoline blow torch in care and operation. It comprises a combined air and alcohol tank, two jet control valves, an air pump, a torch tube, and a heating trough.

Its main point of difference from the gasoline torch is the two-jet control as compared to one in the usual gasoline torch; one of these valves controls the alcohol feed to the jet and the other controls the air.

The air feed is taken from the top of the common tank while the alcohol feed is taken from the bottom of the same tank.

Like the gasoline torch, its tube and jet must be heated by the flame from the trough before the jet is opened and the vapor ignited. For this purpose, alcohol is introduced into the trough and lighted in the same way as gasoline in the case of the gasoline torch.

When the tube and jet have heated sufficiently, the air and alcohol valves are opened and regulated so as to give the proper mixture for a hot, pointed flame.

The same precautions relative to excessive air pressure and the slight reopening of the control valves to prevent "freezing" of valve stems, which apply to the gasoline torch, also apply to this torch.

The ability of this torch to maintain its flame in a breeze is its main advantage over other alcohol torches. The other alcohol torches are dependent upon the maintenance of the wick flame for operation and a slight breeze may extinguish this flame.

If pure grain alcohol is always used in this torch, good service will be had from it. The use of "pink lady" or other variations will cause clogged feed pipes and jets and produce an erratic flame.

The *automatic alcohol torch* comprises two alcohol chambers, a wick pipe, wick cap, two wicks, a jet tube and jet, a handle, and an entrance to each alcohol chamber (see fig. 9).

The alcohol in one chamber supplies the wick which heats the jet.

The alcohol in the second chamber supplies the wick which runs through the jet tube almost to the jet.

To fill the heater wick chamber with alcohol, the hexagonal nut near the bottom of the torch tank is removed.

To fill the jet wick chamber with alcohol, the hexagonal nut at the base of the handle is removed.

It will be noted while filling the two chambers that the two wicks differ greatly in size, the reason for this being the much larger diameter of the heater wick pipe as compared with the diameter of the jet tube.

When the two chambers contain sufficient alcohol, the wick pipe cap is removed and the wick is lit.

When the flame from the heater wick has heated the jet sufficiently, the alcohol inside the jet tube (which is brought up there by the wick inside the jet tube) will be vaporized.

The expansion which results from this vaporization will produce a pressure inside the jet tube which will eject the vapor out through the jet with considerable force and this vapor will be ignited by the heater flame.

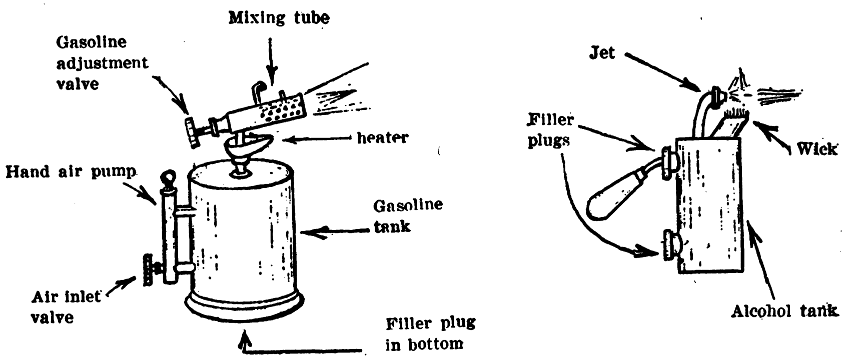
The jet opening may become clogged with a gummy substance when the torch is not in use. This opening must be cleaned with a common pin or other sharp pointed implement before vapor will issue from the jet properly.

The jet flame thus produced is very suitable for soldering lugs, etc.

Like the mouth-operated torch, this torch cannot be used in the wind because the heater flame may be extinguished.

If the jet wick needs renewing (*not* the heater wick) and a suitable wick is not available, a pipe cleaner may be used instead.

When the torch is not in use, the wick pipe cap should be put in place to avoid evaporation of the alcohol from its tank.



GASOLINE BLOW TORCH AUTOMATIC ALCOHOL TORCH

FIGURE 9.

QUESTIONS

1. What relation must hold between the melting point of the solder and the melting point of the metal being joined?
2. What causes oxide to form on heated metals?
3. How do oxides interfere with the process of soldering?
4. What is the first step in preparing surfaces for soldering?
5. What is soldering flux and why used?
6. How do the two classes of flux differ?
7. What kind of flux is best suited for electrical work?
8. Why do different metals require different fluxing agents?
9. What is the action of rosin when used as a flux?
10. Why does heat affect the fluxing life of rosin?
11. What is the most convenient form of flux for radio work?
12. Explain the use of hard solder? What are its advantages?
13. What are the advantages and disadvantages of soft solders?
14. What precautions must be taken in using soft solder?
15. What are the causes of rosin joints and cold solder joints?
16. Explain the correct method of securing work in a vise?
17. Why is it important to avoid overheating?
18. How can overheating best be avoided?
19. Where should solder and flux be applied? Why is this important?
20. Why is copper comparatively hard to solder?

21. How can enameled wire be prepared for soldering?
22. What are the steps in tinning a soldering iron or copper?
23. What precautions should be taken with the needle valve of a blow torch?
24. What are the advantages of alcohol torches?
25. What two kinds of alcohol torches are in general use and in what way do they differ?
26. Why must soldering irons and coppers be tinned?
27. How can you tell when an iron is overheated?
28. What are the advantages of an electric iron over torch-heated irons?

CHAPTER 2. FILES AND FILING

FILES

Files are made from a high grade of crucible steel, forged to shape, teeth cut, and hardened.

File classification is based on the following:

(1) Length of file.
(2) Cut of teeth.
(3) Degree of fineness or coarseness.
(d) Shape of file.

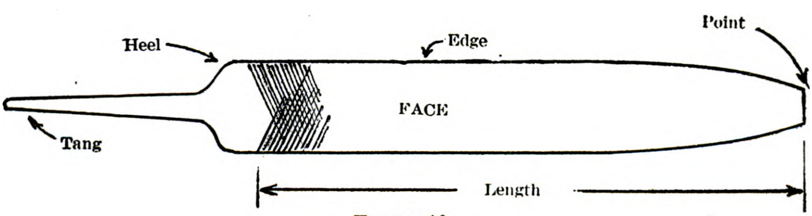


FIGURE 10.

Length.

The length of the file is the distance in inches measured between the heel and the point. The "tang" is the part which fits into the handle, and the "heel" is the portion between the tang and the file proper.

Cut of Teeth.

Files are also divided into classes according to the "cut" or the character of the teeth, usually falling in three classes, (1) single cut, (2) double cut, and (3) rasp.

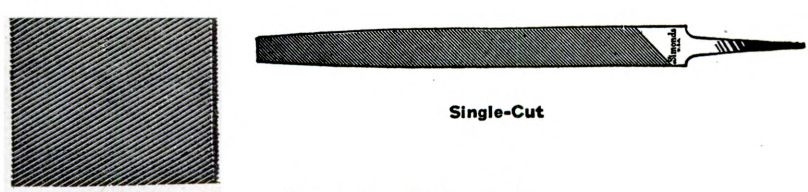


FIGURE 11.—Single cut file.

Single-cut files have one series of teeth, or chisel cuts, running parallel to each other and diagonally across the file at an angle between 65° and 85° with the length of the file.

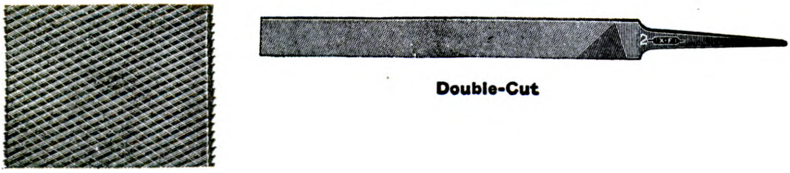


FIGURE 12.—Double cut file.

Double-cut files have two series of teeth, or chisel cuts, one cut over the other. The first row is cut at an angle of 65° to 85° with the length of the file, while the second row is cut at an angle of about 45°. Special files are made with the angles of these two cuts varying widely.

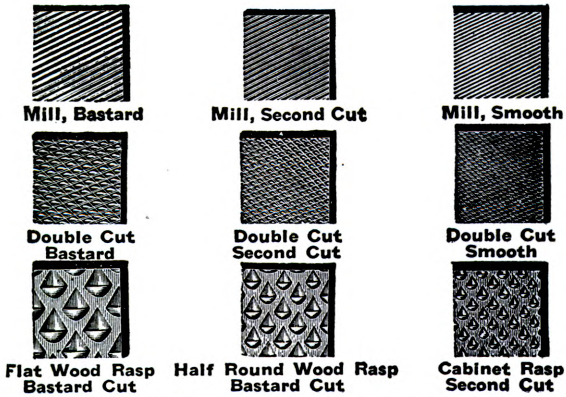


FIGURE 13.—Comparative cuts of files.

The rasp has each tooth cut separately by raising a small portion of the surface of the stock with a punch, as shown in figure 13.

Degree of Fineness.

Files are also classified according to the fineness or coarseness of the teeth. The number of rows of teeth vary from about 20 to 120 per inch. Named in order from coarse to fine, the various cuts are classed as follows:

Rough	Second-cut
Coarse	Smooth
Bastard	Dead-smooth

Files usually available for general use on board ship and in the ordinary machine shop are bastard, second-cut, and smooth. These three are compared in figure 13.

File Shapes.

Files may be had in many different shapes, the most common of which are listed below.

Mill	**Half-round**
Flat	**Knife**
Warding	**Hand**
Square	**Three-square**
Round	**Rasp**

Mill files are tapered in *width* and *thickness*. They are used for lathe work and draw filing.

Flat files are tapered in width and thickness. They are general purpose files.

Warding files are flat, about half the thickness of other flat files and they taper sharply to almost a point. Their chief use is on work where space is limited.

Square files are tapered on all sides. They are used for enlarging rectangular shaped holes.

Round files are principally used for enlarging round holes and shaping fillets on internal angles. A small round file is known as a "rat-tail" file.

Half-round files.—The convex side of this file is used for curved work, while the flat side is used as are other flat files.

Knife files are tapered in width and are thicker at one edge than at the other. They are used for filing key ways, etc.

Hand files are flat and do not taper toward their tips but they do taper somewhat in the thickness.

Three-square files are tapered on all sides, each side at a given point is of equal width. They are also known as taper files, triangular files, and hand saw taper files. They are principally used for filing taps, cutters, acute internal angles, and to clear out square corners.

Flat wood rasps are used for working wood.

Safe Edges.

A safe edge on a file is an edge without teeth. Most any type of rectangular file may be had with one, two, and even three safe edges. Hand files are sometimes made with one safe edge.

This type of file is useful where only one surface is to be cut such as forming a key-way and working in corners.

Teeth Construction.

The teeth of a file must necessarily be very hard in order to cut other metals and are therefore very brittle and easily broken.

Pressure on the stroke away from the body places the pressure on teeth as shown by "A", figure 14. The teeth are so constructed that they can bear the pressure at this angle.

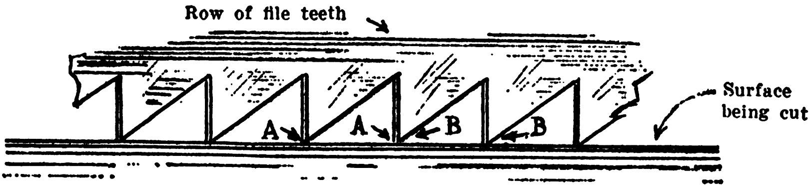


FIGURE 14.—Illustrating relative angle of teeth.

The pressure exerted on the return stroke, or by being hit or laid against other tools results in pressure as shown by "B". At this angle the thin sharp edge has very little strength and is easily chipped off.

FILING

Filing has to be done in nearly all cases where work must be finished by hand. The quality of the work depends entirely on the skill of the workman, and although it seems to be a very simple operation, it is quite difficult to do properly.

The work should be held firmly in a vise, the surface to be filed being about the height of the workman's elbow.

Stand squarely in front of the work, the feet parted a few inches, one foot slightly in front of the other.

With a file that is fairly coarse for the work, work the metal down to the approximate dimensions.

Next, using a finer grade of file, work the metal closer to the dimensions, which should remove all marks of the coarse file.

Finally, with the use of a smooth file, bring the metal down to the exact dimensions.

Methods of Filing.

Filing may be divided into two classes:

1. Cross filing.
2. Draw filing.

Cross filing is the most generally used method of filing. It is the method which removes the greatest amount of metal in the shortest time, and requires the least pressure on the file.

In this method the point of the file is held between the first finger and thumb of the left hand, while the handle is held in the right hand with the thumb resting on the handle.

The file is moved across the metal in a direction parallel with the length of the file, or slightly diagonal.

Pressure on the file, depending on the size of the file and the metal being cut, is exerted on the stroke *away from the body. No pressure should be used on the return stroke.*

Pressure on the return stroke will dull or break the teeth of the file.

Care must be taken that the edges of the work are not rounded.

Rounded edges on a piece of work may be caused by exerting too much pressure on a file, causing it to bend (fig. 15). Rounded edges will also be caused by a slight swinging of the hands in an arc about the joints of the arms when working. Avoid using the work as a fulcrum while the file rests on the different points throughout its course.

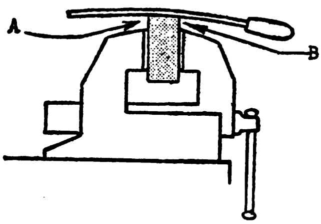


FIGURE 15.—Too much pressure on file causes it to bend on the stroke, resulting in rounded corners at A and B.

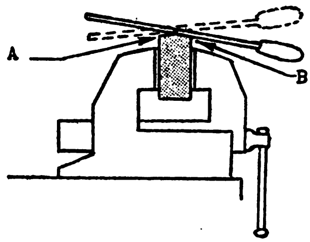


FIGURE 16.—Rocking the file during the stroke will round off the corners at A and B. This is a common error in filing narrow surfaces.

Draw filing is done to finish up work. The file is held across the work, and the stroke is at right angles to the length of the file. Due to the angle of the teeth, cutting is done only on the stroke away from the body. As in cross filing, no pressure should be exerted on the return stroke.

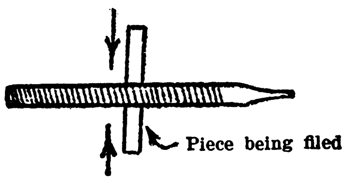


FIGURE 17.—Position of the file and direction of stroke in *draw filing.*

In draw filing both hands should be placed on the file fairly close to the work to prevent bending of the file.

In filing *round holes*, a file as near as possible the diameter of the hole should be used. This will prevent formation of ridges.

PINNING

"Pinning" is the wedging of minute pieces of metal (pins) between the teeth of the file. A wire brush called a "file card" is used to keep the file clean. However, it is sometimes necessary to remove pins with a pointed instrument or the corner of a piece of metal. Filing a piece of brass parallel with *the deepest cut row of teeth* is helpful in removing pins.

Pins, unless removed, are apt to mar the surface being filed.

Pinning may be partially prevented by filling the teeth of the file with chalk.

CHATTERING

Files were first cut with regularly spaced teeth. This was soon found objectionable, because the teeth, in following each other at regular intervals, would drop into the cuts made by preceding ones, causing "chattering."

This difficulty in machine-cut files was overcome by gradually increasing the spaces between the teeth from one end of the file to the middle, and again decreasing as the opposite end is approached. This is known as the *increment cut.* There is, however, no set rule as to where these space variations shall begin or end.

COMMON USES OF FILES

It is recommended that the following suggestions be observed in the use of files:

(*a*) For soft materials in general, such as aluminum and copper, a coarse deep-toothed, single-cut, file is satisfactory.

(*b*) The *best* file for aluminum and copper, if obtainable, is the Vixen file. This file has its teeth arranged in curves rather than straight or obliquely across the face of the file. The cutting stroke is against the convexity of these curved teeth and for this reason the Vixen file is, to a considerable extent, self-cleaning, and will not clog or foul nearly as soon as most other types of files.

(*c*) The harder the materials to be filed the finer the "file cut" that should be used.

(*d*) A medium or fine grade of file cut should be used where the material is comparatively thin copper or aluminum sheeting *edges*, rather than the coarser files that are recommended for general copper and aluminum work. Too coarse a file used on metal sheet edges turns the edges over and does a ragged job.

(*e*) Materials to be filed should be firmly secured in a vise, or otherwise rigidly held.

(*f*) When considerable *depth* of filing is to be done use a reasonably coarse file for the particular material being cut, until within a small faction of an inch of the exact working line, then finish with a finer grade of file.

CARE OF THE FILE

Clean the file frequently with a file card while using it, and do not use a file without first examining it for pinning.

Oil should never be used on a file nor should oily surfaces be filed. The teeth will tend to slip over the work rather than cut.

New files are often oiled to prevent rust. Before using a *new file* see that it is clean and free of oil.

Exercise care in selecting the file for the job. New files should not be used on new cast iron nor on narrow surfaces. Such usage tends to break or dull the teeth. An old file will do just as well in these cases.

An *old* coarse file should be used for filing solder or lead.

In *all filing* there should be just enough pressure applied on the forward stroke to cause the file to cut, and *no pressure* should be applied on the return stroke.

Like any other tool a file should be properly handled, and kept in its proper place when not in use, where the teeth cannot be damaged. *Files should never be placed one upon another*, much less thrown together. They should be hung up separately, or stowed in drawers or on shelves provided with small divisions that do not permit them to touch each other.

QUESTIONS

1. In what ways are files classified?
2. Name and locate the various parts of a file?
3. What are the classes of teeth cuts?
4. What are the limits of teeth per inch in commercial files?
5. Classify files as to fineness.
6. In what other ways are files classified?
7. What shapes are generally encountered?
8. Where and why is a safe edge used?
9. How can a file be given a safe edge?
10. What is the cutting stroke?
11. On what stroke must the file be raised? Why?
12. What file should be used for starting? Finishing? Why?
13. What are two methods of filing?
14. When is cross filing advisable?
15. In what two ways are corners unintentionally rounded?
16. What type of file used in enlarging holes of various sizes?
17. How can pinning be partially avoided?
18. Name two methods by which pins can be removed.
19. Explain increment cut.
20. What files should be used on thin edges?
21. How should files be cleaned and cared for?
22. What is the effect of oil on a file?
23. Why must teeth be protected?
24. What is the effect of heat on a file?

CHAPTER 3. TYPES OF DRILLS, LAYOUT, DRILLING—TAPS AND TAPPING

DRILLS

The most generally used drill for boring small holes in metal is the straight-shank "twist drill" shown in 3.8, figure 18. Ordinarily these drills are made of a high-carbon steel of excellent quality, and are suitable for most all classes of work if used properly and never allowed to become heated. Drills made of a special alloy containing tungsten, chromium, and especially cobalt, are referred to as "high-speed" drills, which cost several times as much as ordinary carbon drills, but which may be operated at quite high temperatures and still retain their hardness. High-speed drills are preferred when large numbers of holes are to be drilled in bakelite or other plastics, especially when the drill must be driven by a small portable electric drill that operates at very high speed. This is because the plastics are very poor conductors of heat, and any heat produced while drilling will accumulate in the drill instead of being conducted off through the work. Monel metal, stainless steel, and other extremely tough materials produce so much heat when drilled that the use of high-speed drills is imperative.

There are two standard systems of designating the diameters of small twist drills, which are known as *wire* twist drills, and *jobbers* twist drills. The wire sizes are designated in gage numbers of a special "Drill and Steel Wire Gage" having gage numbers from 1 to 80 as shown in table 3.1, figure 19. The drill outfit normally furnished to radiomen aboard ship is a set of carbon steel, wire twist drills, sizes 1 to 60, inclusive. Size numbers 61 to 80 are so small that they are practically never used by radiomen.

3.31, figure 18, illustrates a gage for determining the gage numbers of wire twist drills, and is used by trying the *shank* end of the drill into various holes until one is found which just fits. The gage gives both the gage number and the diameter in decimal parts of an inch. Drill points should never be inserted into the holes of the gage as this will ruin both drill and gage.

Jobber's sizes of twist drills look exactly like wire twist drills except that they are somewhat longer for a given diameter. The diameter of jobber's drills is designated in fractional parts of an inch, and they are available in multiples of $\frac{1}{64}$ inch from $\frac{1}{32}$ up to $\frac{1}{2}$ inch in diameter. Straight shank twist drills, and twist drills with "Morse Taper" shanks, are listed as standard in sizes up to $1\frac{1}{2}$ inches in diameter. Jobber's sizes of twist drills are not very often used in sizes smaller than $\frac{1}{4}$ inch because the wire sizes offer a much wider choice of sizes for special purposes.

To meet the need for exact sizes for specific uses (such as tap drills, etc.), and which are not available from either the wire or jobber's sizes, there is a series of "letter" size drills. The diameter is indicated by one of the letters of the alphabet, and the actual diameter may be found by referring to a table. The Navy radioman very seldom has need for drills of this type, as the nearest standard fractional size will probably serve just as well.

Nomenclature.

A twist drill has three principal parts which are known as the *point*, the *body*, and the *shank*. The point is of greatest interest because it is the part that does the cutting, and which must be resharpened (ground) occasionally with extreme care if good results are to be expected.

Points.

The entire cone-shaped region at the cutting end of a drill is referred to as the point. The sharp edge at the extreme tip is called the "dead center," or just "center," and is the part that does the first cutting, thereby determining to a great extent how fast the drill will penetrate. The angle of the center is quite important, and should be about 118°, or 59° each side of the center line through the drill, as shown in 3.1, figure 18, for all general uses. For cutting very hard metals, like armor plate or forgings, the angle should be greater, say about 150°, and the drill subjected to more pressure. Similarly, a drill for soft metals, plastics, or wood, may have a very small angle (see 3.6, fig. 18) so that it will cut rapidly without requiring much pressure.

After the center of the drill penetrates, the cutting is done by the "lips" of the drill point (see "a," 3.7, fig. 18). The faces of the lips present an angle to the work which is determined by the amount of twist in the drill, or in the manner in which it is ground. Figure 18, illustrations 3.4 and 3.5, shows a special purpose drill sharpened especially for use in brass, and which has the lip faces ground so as to present a 90° angle with the metal being cut. Regardless of whether or not the leading edges of the lips have been altered by special grinding, the cutting edge must have relief, or "clearance," behind it in order that it can dig in and cut the metal. This "lip clearance" angle is practically always about 12° as can be seen in 3.2, 3.5, and 3.6, figure 18. This angle will also affect the angle that the center makes with the leading edge of the lips, which should be 135° as shown in 3.3, figure 18. The back edge of the point, that is, the noncutting part, is called the heel. Shortening the heel is what creates the lip clearance and alters the angle between the dead center and lips.

Body.

The body of a drill has a spiral groove or "flute" cut in each side as shown at "d" in 3.7, figure 18. In the straight-shank drill, the length of the body is considered as the length of the flutes. The flutes are cut quite deeply and remove all but a thin section of metal down the center of the drill, which is referred to as the "web," and determines the length of the cutting edge of the dead center, as shown in 3.3, figure 18. The raised leading edge of the body of the drill (see "c," 3.7, fig. 18) is the "margin," and is very accurately ground to size. The remainder of the surface of the body recedes from the margin to form the "body clearance" as can be seen at "b" in 3.7, figure 18, and as an end view in 3.3, figure 18.

Shanks.

Small drills for general use almost invariably have straight shanks as shown in 3.8, figure 18, the shank being exactly the same diameter as the "margin" of the body of the drill. Straight shanks are to be used only in drill chucks of the three-jaw type, which are made especially for this purpose, and are found on hand drills (see 3.18, fig. 18), portable electric drills, and most small drill presses. Every effort should be made to preserve the smoothly machined surface of drill shanks, and chucks must be tightened very carefully to prevent slippage which results in damaged shanks. Good quality electric drills and small drill presses nearly always use a three-jaw chuck which has a key for tightening, the most popular (and by far the best available) being known as the "Jacob's" chuck. Straight-shank drills will last indefinitely when used with such a chuck providing it is always tightened sufficiently to prevent the drill from being scored by slipping. Breast drills (see 3.19, fig. 18) sometimes have three-jaw chucks, but this is not the general rule. They usually have a two-jaw, so-called "universal" chuck which will instantly ruin a straight-shank drill, and is suitable only for drills having a square shank of some sort to prevent slipping.

The best possible method of driving twist drills larger than 1/4 inch is by means of the "Morse taper" shank, shown at 3.7, figure 18. The tapered shank slips into a very accurately ground socket instead of the customary chuck, the taper holding the drill in exact alignment. The drill is prevented from slipping by a "tang" (see "e" at 3.7, fig. 18) which extends beyond the end of the taper. Drills with tapered shanks should *never* be used in a breast drill, bit brace, or any type of drive other than a Morse socket, and every effort should be made to keep both socket and taper smooth, clean, and free of particles of metal, etc. There are several sizes of Morse tapers to suit varying needs, and are designated by numbers. For example, drills from 1/4 to 1/2 inch in diameter have "No. 1 Morse taper," the next group from ½ inch up has No. 2 taper, etc. To fit a drill with a No. 1 Morse taper shank into a drill press fitted with a No. 2 Morse taper spindle, an adapter "sleeve" is used. Practically all drills used aboard ship in sizes greater than ¼ inch will be found to be of the tapered shank type. A "Jacob's" chuck mounted on a Morse taper shank serves as an adaptor for using small straight-shank twist drills in a drill press having a Morse taper spindle.

Both wire and jobber's twist drills are also available in several other types of shanks, although they are not standard in the Navy, and are not used ashore except for special purposes. Common types are "bit-stock" shanks like those furnished on a carpenter's auger bit (see 3.9, fig. 18) and are to be driven by a breast drill with the "universal" chuck, or a carpenter's bit brace (see 3.20, fig. 18). There is another series having straight shanks with a flat ground on one side so that they may be used in the two-jaw universal chuck, or in a common spindle using a set-screw to hold the drill from twisting.

Grinding.

There is quite an art in sharpening a twist drill by hand, and it is acquired only after considerable practice, and by paying particular attention to the proper angles and clearances that are essential if good drilling is to be expected. The most important are the angle of the lips, and the lip clearance, the other details usually taking care of themselves if these first two are accomplished with great accuracy.

The lip angle is practically always ground to 59° where drills are to be used for all general purposes, but the exact value of this angle is of minor importance. It is extremely important, however, that both lips have exactly the *same* angle, whatever that be, and that the lips are both of exactly the same length. This is to insure that both lips cut uniformly, and that all the work is not done by only one of the lips. Furthermore, if both lips are of exactly the same angle and length, the dead center will actually be in the center of the drill, thereby avoiding the drilling of oversized holes. 3.1, 3.2, and 3.3, figure 18, illustrate perfectly ground drill points for average work, and 3.14, figure 18, illustrates the use of a drill gage for checking the angle and length of lips while grinding. The drill will not cut unless sufficient lip clearance is provided (see 3.2, 3.5, and 3.6, fig. 18) to allow the cutting edge to cut into the metal, as otherwise the drill will slip over the work causing great friction resulting in burning the drill point. It is quite difficult to grind this clearance properly and still maintain the proper proportions of length and angle of the lips. A good check is to note that the angle between the point and the lips (see 3.3, fig. 18) will be 90° if there is no lip clearance, but this angle will increase to 135° when the lip clearance angle is increased to 12°.

In the actual grinding operation there are other precautions to be observed, the most important being the preservation of the proper hardness and toughness imparted to the drill by special heat treatment at the time of manufacture.

Heating the drill even to comparatively low temperatures and allowing it to cool will "temper" (meaning "reduce hardness") a carbon steel drill, which makes it necessary to quench the drill in water every few seconds of grinding to insure that the drill does not become hot. A carbon drill that has become blue with heat in sharpening is most likely ruined, and is a sign of carelessness and deliberate waste. Drills made of high-speed steel should *not* be quenched in water if they become too hot, but instead should be allowed to cool slowly in still air. When grinding high-speed drills they may be kept cool with water by repeatedly dipping them every second or so of grinding to insure that they never become even slightly heated. High-speed steel can be recognized by its characteristic color, the color of sparks it makes when ground, and the color of the dust it leaves, but for a person without experience it is best to look for some marking on the shank, such as "HS" or the words "high speed" spelled out. High-speed steel is not necessarily (and seldom is) any harder than carbon steel, its main advantage being that it can operate continuously at very high temperatures and still retain that hardness. It will be completely ruined, however, if subjected to rapid cooling by quenching in water.

Wheels for grinding drills should have a medium grit, preferably be of fairly large diameter, and must be dressed to run perfectly smooth and true. The drill should be grasped as near to the point as possible with the right hand, and by the end of the shank with the left hand, and should be held lightly against the wheel. Some prefer to grind drills on the side of the stone, and others on the face, although there is very little difference in the results except when the diameter of the wheel is less than about 8 inches it is easier to use the side of the wheel. Grinding should start with the cutting edge of one lip, at a 59° angle with the stone, and while twisting the drill slowly clockwise this angle should be decreased to about 50°, thus forming the lip clearance. Don't wait for the drill to become blue or your fingers to get burned with the heat before cooling the drill in water! The water should be provided first, and the drill should be rapidly agitated in the water every second or so while grinding. A drill can be burned very easily on the wheel before realizing it because the steel is such a poor conductor of heat that the point might easily be ruined before the remainder of the drill becomes too hot to handle. Each time the drill is cooled in water it should be inspected and compared with the drill grinding gage (3.14, fig. 18). In grinding drills of ¼ inch and smaller, the drill grinding gage is not of much value, the unaided eye usually serving better to judge if the lips are of the same angle, same length, and the "center" actually in the center. An experienced machinist practically never uses the gage for small drills, and they are very often not even available.

Special Drills.

A "Wyco" hole cutter is shown in 3.17, figure 18, and is typical of several devices on the market for cutting large holes in thin metal, such as holes required for mounting meters in radio panels, etc. They may have either one or two blades, and are variously known as "panel cutters," "washer cutters," and sometimes as a "sweep." They have a "pilot drill" which enters first and serves as a pivot for the sweep. They must be run at very low speeds, and are extremely difficult to use except in a drill press. Another similar device is a cup-shaped saw arrangement also having a pilot drill in the center. These "hole saws," as they are called, are somewhat better for thin metal than the sweep. In very thin metal, and for substances like rubber, fibre, gasket material, canvas, etc., the hollow punch (see 3.12, figure 18) may be used. The material to be punched is best placed on a wooden block which is made so that the grain in the wood will be vertical, the force of the punch then being taken up by the end-grain of the wood. If the hole is quite large, or of irregular shape, it is best cut out by means of a cold-chisel of the "cape" pattern as shown at 3.13, figure 18.

Figure 18, 3.25, illustrates a countersink for reaming the cone-shaped recess to accommodate the heads of flat-head screws. This particular pattern is made especially for cutting metal, and may be used in a hand drill or drill press, although it must be turned quite slowly to avoid burning. When selecting a countersink it is very important to note that the angle must be 82° for flat or oval head screws, and if the angle is other than this it cannot be used as a countersink. When the device illustrated at 3.25, figure 18, is supplied with an angle of 60° it is correctly referred to as a "center reamer," and is used only to ream center-holes in objects that are to be turned between centers on a lathe. A combined center-drill and countersink (or center-reamer) is shown at 3.29, figure 18, and is for simultaneously drilling and reaming a center-hole as described above for use in a lathe, and cannot normally be used as a countersink for screws because it has an angle of 60° instead of 82°. A "rose" countersink (82°) with a "bit-stock" shank, is shown at 3.26, figure 18. The bit-stock shank is to fit a carpenter's brace or a breast drill with a universal chuck and, although the rose countersink is intended primarily for use in wood, it may be used with caution in soft metal. When socket-head cap screws or screws with fillister heads are to be countersunk, it is necessary to make a cylindrical-shaped recess with a flat bottom. This is done by means of a "counterbore" (see 3.30, figure 18) having a small "pilot" which precedes the cutting edges and guides them concentrically with the previously drilled body clearance hole.

For drilling holes in stone or cement, bricks, tile, etc., a "star" drill (so named because of its shape) is used. This type of drill (see 3.11, fig. 18) is driven by means of a heavy hammer, and must be continually rotated while being driven. Larger holes in soft brick or cement may often be drilled more rapidly with a section of pipe of the proper diameter and which has saw teeth cut in the drilling end. It is used like a star drill. Holes may be drilled in wood with ordinary twist drills, which will do a pretty good job in hardwood if the drill is run at a very high speed. A better drill for use in wood, however, is the "auger-bit" shown at 3.9, figure 18, which is made especially for boring holes in wood. Auger bits have "bit-stock" shanks which are made especially for use in a carpenter's "bit-brace" (see 3.20, fig. 18) or a breast drill having the "universal" type of two-jaw chuck. Auger bits which may be adjusted to cut different diameters of holes are called "expansion" bits, and are constructed along the same general lines as the sweep, as shown in 3.10, figure 18.

LAYOUT

General.

Accurately located holes require first that the exact location of the holes be properly marked and then punched as an aid in starting the drill. The engineer's "combination square" (see 3.15, fig. 18) is of great help in accurately laying out the work prior to punching. Such a square consists of the "handle" and the "blade," the one illustrated being also equipped with a "protractor head" and a "center head," and as such, is known as a "combination set." The protractor head is adjustable as to position on the blade (as are the other attachments) as well as to angles with the blade. The center head facilitates the marking of the exact centers of the ends of shafts and other round objects. Rough work on sheet metal is usually marked with a "scratch awl" (see 3.23, fig. 18), but accurate marking is best done with a very sharply pointed "scriber" as shown in 3.24, figure 18. Good combination squares usually have a small scriber that is kept in the handle when not in use. When scribing lines on accurate work, care must be taken to avoid *parallax* error due to the thickness of the rule or blade of the combination square. This is easily avoided by always setting the scale up on its edge where the graduations are actually in contact with the face of the work, rather than being separated from the work by an amount equal to the thickness of the rule. Lines should be scored no more deeply, nor over any greater area, than is absolutely necessary if the finished job is to present a neat appearance.

Punching.

After the center of the location of the hole is accurately marked by two intersecting lines, the point of intersection is first marked by means of a "prick" punch, and then it is center-punched. The prick punch (see 3.28, fig. 18) is small and has a very sharp and accurately ground point. It should be held close to its point, placed carefully into position, and given a light tap with a machinist's hammer. If, after inspection, the punch mark is not exactly in the desired place, it can be moved somewhat by inclining the punch at an angle and giving it another light tap. This should be done cautiously and the work should be inspected after each light blow. When the location is considered satisfactory, it should then be center-punched. The center punch (see 3.27, fig. 18) is similar to the prick punch except that it is made much heavier, and has a larger and more blunt point which is comparable to the 59° point of a standard twist drill. It is held and used in the same manner as the prick punch, but it takes a much heavier blow to drive it into the work. Center punches should always be kept ground to a perfect cone-shaped point of approximately 59° angle. When the requirements of location are not too exact, and if the center punch is carefully sharpened, it is not necessary to use the prick punch previous to center punching. Similarly, when very small diameter drills are to be used, the center made by the prick punch is usually sufficient, and the use of the center punch is then neither necessary nor desirable.

DRILLING

Care of Drills.

Outside of actual breakage, the only serious casualties to drills are *burning* of the points, and *scoring* of shanks. The point of a drill is said to have been burned if it has been heated to such an extent that the metal has lost its hardness. Burning is caused by too much speed, or, more often, by friction created when the drill turns, but does not cut. Carbon drills are very often burned in high-speed electric hand drills because the operator does not push hard enough on the drill to keep it cutting, the drill instead creating a burning temperature by friction. A drill of carbon steel should be turned slower and pushed harder to avoid burning. Lubricants sometimes help to prevent the burning of drills, but they can actually expedite burning unless the drill point is forced into the work with sufficient pressure to keep the cutting edges from slipping over the metal instead of cutting into it. The lubricant is probably of greater use as a "coolant" in this respect, and carbon drills should be instantly quenched in water at very frequent intervals if there is the slightest tendency toward heating. Drills made of "high speed" steel can be safely operated at temperatures that would ruin a carbon drill but they should *never* be quenched in water. Water or any other coolant can be employed to *keep* a high-speed drill cool, but once it gets hot it should be allowed to cool very slowly in still air. When a lubricant is desired, turpentine or kerosene is quite good for hard steel or aluminum. Lard oil, or common lube oil, is satisfactory for soft steel. Brass and cast iron are drilled best when dry, although a blast of air may be used as a coolant. A burned drill may be identified by the "blued steel" color of the ruined area.

Drills with scored shanks cannot be expected to run perfectly true, and they will also ruin the chuck by contact with their rough, gouged surfaces. The chuck should be kept in perfect condition at all costs, as a poor chuck will eventually ruin all drills used in it. It is better to discard a drill with a ruined shank than to run the risk of damaging the chuck as a result of using the drill.

Pilot Holes.

When drilling large holes in thick metal, greater accuracy of hole location and better drilling performance will result when a pilot hole has previously been drilled. The drill used for the pilot hole should be about the same diameter as the thickness of the web of the large drill, which is normally about 12 to 18 percent of the diameter of the drill. Holes larger than about $\frac{1}{4}$ inch cannot be drilled in sheet metal, as the point of the drill breaks through the other side before the margin can guide the drill point. This results in egg-shaped holes which are never in the right place, plus very serious gouging, which tears the metal and very often jams the drill. If the work is very securely fastened in place, jamming of the drill will either stall the machine or break the drill. If the work is not bolted in place, however, the work will whirl around with the drill, and can deal very serious cuts to the operator. *Never* attempt to drill sheet metal with a drill so large that the point can cut through the metal before the margins have started cutting, unless the work is very securely fastened to the bed of the drill press with bolts or **C** clamps (see 3.16, fig. 18). Even this procedure does not prevent the holes from creeping off center, or being out of round and oversized. The only way to drill holes in light stock satisfactorily is to clamp the piece rigidly between two thick sections of metal, and drill the hole through all three. The work must be held rigidly in the drill press, or in a vise.

Procedure.

After laying out, punching, drilling pilot holes, etc., the work should be rigidly anchored to the drill press unless the holes are quite small and the work large enough that there will be no difficulty in holding the work against the torque of the drill. To avoid cutting the fingers, small pieces should be clamped in a vise when drilling with a portable electric hand drill. When using the drill press, small pieces are most conveniently held in a drill-press vise (see 3.22, fig. 18). An accessory jaw face, shown in 3.21, figure 18, can be inserted between the work and one of the jaws of the vise to facilitate holding round or irregular shapes. When drilling holes up to about 5/16 inch in diameter (except when the metal is thin) the drill-press vise can be held down by hand, but when drilling larger holes the vise must be bolted to the bed of the drill press, or held in place by means of C clamps. The work should be oriented so that the drill point runs exactly over the punch mark in the work, and the drill must never be allowed to get out of alignment while drilling. Drills will invariably be broken if there is the slightest bending due to misalignment between the axis of the hole being drilled and the axis of the drill.

Speed.

It is impossible to establish an absolute rule governing the speeds and feeds of drills owing to the great variation in the hardness and density in different runs of metals, and also to the character and form of different pieces to be drilled, that is, whether the piece is hard or soft, large or small, thick or thin. The following brief table gives a very rough approximation of maximum drill speeds (in revolutions per minute) for average conditions for drills of several sizes:

DRILLING

Drill diameter	Carbon drills		High-speed drills	
	In steel	In brass	In steel	In brass
Inches				
1/16	1,800	4,800	3,600	7,200
1/8	900	2,400	1,800	3,600
3/16	600	1,600	1,250	2,500
1/2	200	600	450	900

The amount of feed per revolution will vary from about 0.004″ to 0.010″ and is in general the same for both carbon and high-speed steel drills, the greater efficiency being obtained from high-speed drills by virtue of the increased speed rather than by an increase in feed. If a drill chips at the cutting edge, or the corners of the cutting edges wear away very rapidly, it is evidence that too much speed is being given, or that the drill has been ground with too much lip clearance.

The maximum speed at which drills may be safely operated is of great importance to a factory production manager, but is of minor

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importance to the casual user of drills, provided of course that these speeds are never approached. Lacking the intimate experience of a professional machine-tool operator, it is best to run drills quite slowly, and to proceed with caution. This applies to the feed as well as the speed, as cutting edges will disentegrate or the drill will break under too much feed, or, which is the same thing, too much pressure. Too little feed results in burning the drill point, and is a common mistake made by casual users of drills, who, in an effort to be cautious, will actually ruin a drill by not pushing hard enough to make it cut properly.

Burrs.

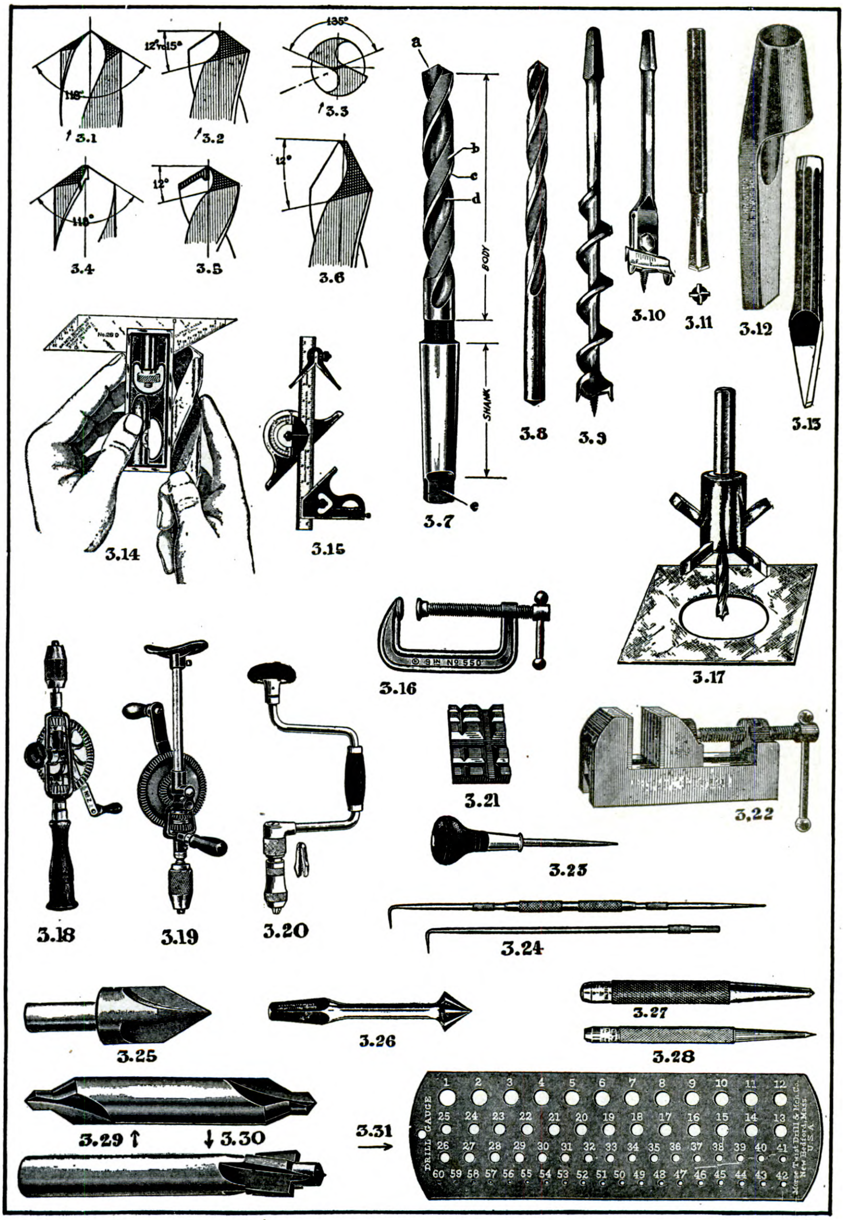
After holes have been drilled, it is a good idea to remove all the burrs which are invariably formed during the drilling operation. This may be done by filing the surface of the work with a flat file, or by cutting a narrow champher or bevel around the edges of the hole with a countersink or center-reamer. A very neat job can be done with a larger size drill, but only when the holes are fairly small and in thick metal. The twist drill for removing burrs should be about twice the diameter of the hole to be champhered. Holes in thin sheet metal may sometimes be champered by means of a larger twist drill, but the drill must be held in the hand and twisted like a hand tool.

TAPS AND DIES

Taps.

A tap is an instrument for cutting internal threads, and may be known as a *hand tap* or *machine tap*, depending upon whether it is to be turned by hand or by power. Taps are made of an extremely hard and brittle steel in order that they will cut metal, and are therefore very easily broken by an inexperienced operator.

A set of *hand taps* is shown in 3.32, figure 19, and consists of three identical taps except for the points, and are known as "taper," "plug," and "bottoming" taps respectively. The tapered tap is sometimes referred to as a "starting" tap, as the taper permits it to cut more slowly, turn more easily, and in general give better performance. When holes are to be tapped clear through, or when there is no obstruction of the end of the tap, the taper tap should always be used. The "plug" tap has a very much shorter taper to its point, but is still a more or less general purpose tap. It can be used to tap "blind" holes provided they can be drilled deep enough to allow clearance for the point of the tap. Generally, however, a plug tap should never be used for any application where a taper tap could be used. "Bottoming" taps are special purpose taps for threading to the very bottom of "blind" holes, and should never be used for any other purpose than cutting the last two or three threads in such holes.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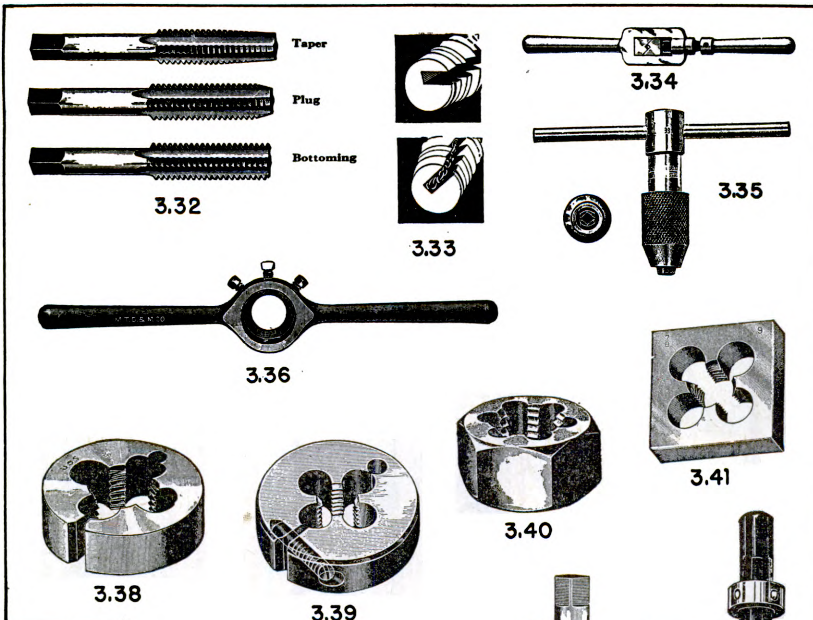
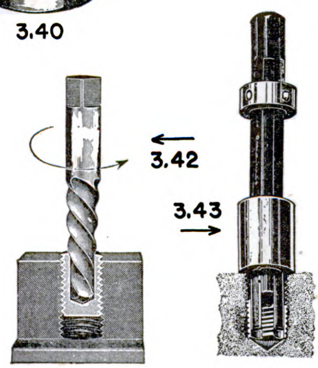
BODY
SHANK
DRILL GAUGE

FIGURE 18.





Twist Drill and Steel Wire Gage: (Table 3.1)

No.	Size of No. in Decimals	No.	Size of No. in Decimals	No.	Size of No. in Decimals	No.	Size of No. in Decimals	No.	Size of No. in Decimals
1	.2280	17	.1730	33	.1130	49	.0730	65	.0350
2	.2210	18	.1695	34	.1110	50	.0700	66	.0330
3	.2130	19	.1660	35	.1100	51	.0670	67	.0320
4	.2090	20	.1610	36	.1065	52	.0635	68	.0310
5	.2055	21	.1590	37	.1040	53	.0595	69	.0292
6	.2040	22	.1570	38	.1015	54	.0550	70	.0280
7	.2010	23	.1540	39	.0995	55	.0520	71	.0260
8	.1990	24	.1520	40	.0980	56	.0465	72	.0250
9	.1960	25	.1495	41	.0960	57	.0430	73	.0240
10	.1935	26	.1470	42	.0935	58	.0420	74	.0225
11	.1910	27	.1440	43	.0890	59	.0410	75	.0210
12	.1890	28	.1405	44	.0860	60	.0400	76	.0200
13	.1850	29	.1360	45	.0820	61	.0390	77	.0180
14	.1820	30	.1285	46	.0810	62	.0380	78	.0160
15	.1800	31	.1200	47	.0785	63	.0370	79	.0145
16	.1770	32	.1160	48	.0760	64	.0360	80	.0135

3.44

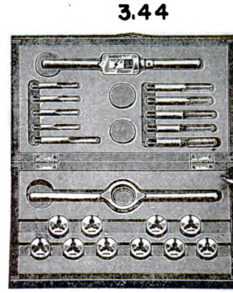


FIGURE 19.

The taps most commonly used by radiomen are "machine screw" taps, a variety of hand taps which cut standard NC or NF machine screw threads. The appearance of machine screw taps is similar to the hand taps illustrated in 3.32, figure 19, except that they are somewhat longer for a given diameter, and the shanks are the same diameter as the major thread diameter. Machine screw taps are available separately in "plug" pattern, or may be obtained in sets of all three types for any given size.

Hand taps are made up with a square shank by means of which they are held in a "tap wrench." A common type of tap wrench appears in 3.34, figure 19, while a somewhat more handy T-handle tap wrench is shown in 3.35, figure 19. Wrenches with T handles are also available with a ratchet built into the spindle. The common tap wrench is difficult to use with small machine screw taps and its use should therefore be avoided whenever one of the T type is available.

The Shakeproof Lock Washer Co. manufactures a special "tapping screw" which has a slot (see 3.33, figure 19), that forms the cutting edge and also serves to retain the chips thereby keeping the tap from jamming. This is the only truly "self tapping" screw on the market, and is available in standard NC threads only.

Tap Drills.

A hole of a very carefully determined size must be drilled prior to tapping, drills of this special size being referred to as "tap drills." In general the tap drill is the same diameter as the nominal *minor* diameter of the threads to be cut, although this is subject to alteration depending on circumstances. For cutting threads in bakelite, fibre, or thin sections of metal, the tap drill should be about one size smaller than normal, but if the threads are cut into very hard metals, or if the holes are very deep, it is sometimes an advantage to use a drill that is one size larger than the listed size. Tables of tap drill sizes are determined such that the tap will produce threads which are approximately 75 percent of the full theoretical depth of that size thread. It has been demonstrated that the 75 percent thread is for all practical purposes as strong as a full thread, and is therefore preferred for all general requirements due to ease in cutting and reduced danger of tap breakage. A table of tap drill sizes appears in figure, in the chapter on Machine Screws. When two pieces are to be held together by machine screws, both pieces should never be tapped. One of the pieces should have a hole that will easily pass the entire body of the screw, and is drilled by a "passing" or "body clearance" size drill. The sizes of body clearance drills can be determined by referring to the "outside diameter, inches" column of the table of tap drill sizes just mentioned, or the American Screw Gage diameter table at the top of figure

22, also in the chapter on Machine Screws. Tables of this sort are to be found in practically any twist drill or tap and die catalog as well as any machinist's handbook.

Tapping.

Small machine screw taps, the variety most often used by radiomen, are the most difficult to use without breaking. Inasmuch as the breaking of any tap can be traced to a definite cause, a knowledge of these causes is essential, but will not be of any real benefit unless applied with good judgment, meticulous care, and infinite patience. The most common causes of small tap breakage are misalinement, bending or uneven turning, and jamming.

Misalignment refers to starting the tap in at an angle not exactly concentric with the hole, and will cause the tap to cut deeper on one side of the hole than on the other. The tap will be strained in an attempt to follow the hole, resulting in breakage after only a very few threads have been cut. It is imperative, therefore, that taps be started in exact alinement with the hole, as, once started, they will follow the center of the hole.

A tap becomes quite rigidly imbedded into the metal after penetrating a few turns, and any uneven strain or jerky twisting at this time will invariably cause the tap to snap in two. One of the greatest causes of uneven strain and bending of taps while turning is the habit of using both hands on the tap wrench. When turning in this manner, especially when the tap is small, the operator loses most of the "feel" of the tap, and is apt to push harder with one hand than the other. The best practice with small taps is to grasp the tap wrench firmly in the fist with the tap (or chuck, if using the T-type wrench) extending out from between the index and second fingers in such a manner that it is in alignment with the forearm. This allows all turning to be done by wrist movement, and gives the most sensitive control, especially when the work is held in a vise in such a position that the hole is horizontal.

Jamming is one of the most frequent causes of tap breakage, and the most difficult to explain because it is necessary for the operator himself to actually sense when a tap is beginning to jam by the intimate "feel" of the cutting action through the tap wrench, and this faculty can be attained only through practice. Jamming is caused by chips getting wedged in between the cutting edges of the tap and the finished threads, where they create sufficient friction to break the tap if any further attempt is made at turning. When using taps smaller than about No. 10 or 12 in steel, it is almost impossible to twist the tap more than about one-quarter turn before noticing symptoms of jamming. Reversing the tap about a full turn will usually clean up the threads sufficiently, however, that another quarter turn can then be tapped. In stubborn cases it is best to go back and forth over this previous full turn six or eight times in order to thoroughly clean the threads and provide ample clearance for the tap. In addition to this, the tap should be removed from the hole about once for every full turn, both hole and tap then being thoroughly cleared of chips. This is very important in deep tapping, especially in "blind" holes. This procedure sounds rather slow and tedious and might seem unnecessary to some, but it must be remembered that time spent in being cautious is nothing compared to the time it may take to remove a broken tap, or to replace an entire piece which has been ruined because of a hastily broken tap.

Brass and cast iron are somewhat easier to tap than steel, but they also should be tapped with great caution, the actual care necessary being learned only by experience. Soft "cheesy" metals like copper and especially aluminum are very difficult to tap because the metal is inclined to "flow" instead of cut, it being therefore necessary to continually clear and clean the tap to prevent breakage. The metal will sometimes adhere to the tap without the operator's knowledge, and the tap, thus deformed, will ruin what threads have already been cut.

Tapping is made somewhat easier by the use of lubricants, except in the case of brass and cast iron, which should be tapped only when dry. Lard oil, or even plain heavy lube oil, is very good in mild steel, and is sometimes an advantage in hard bronze. In aluminum or copper some prefer to pack the tap with tallow, while others prefer using kerosene.

Broken Taps.

Large taps are easier to remove than smaller ones, and if the break occurs up near the surface of the work they can be backed out by tapping on the edges of the flutes with a blunt "cape" cold chisel. Two operators, with chisels against opposite flutes, should start in unison with light blows, gradually increasing the force of the blows as necessary. This old method is very effective and will not tend to wedge the tap farther into one side of the hole, as would be the case if only a single drift is used. The "Walton" broken-tap remover, illustrated in 3.43, figure 19, is typical of a number of tap-removing devices on the market. They are made for all sizes of taps from about a No. 8 up, a particular remover being suitable for use with only one size of tap. Directions accompany the device, although the illustration should be self-explanatory. Small machine screw taps can sometimes be backed out by means of a center punch if they have not been too badly jammed. If the metal is thin, it is sometimes possible to drive the remaining portion of the tap the rest of the way through by means of a center punch. When the portion of the tap is fairly small and the metal is thick, it can sometimes be broken up or disintegrated by means of a center punch, the remaining fragments then being picked out. Regardless of the method used, it is very important that every last fragment of broken tap be removed prior to any attempt at subsequent redrilling or tapping, as drills or taps coming into contact with these extremely hard particles will be instantly damaged. In extremely stubborn cases, and where it is impossible or impractical to relocate the tapped hole, the broken tap can sometimes be burned out by means of an acetylene torch, the remaining large hole welded up, the surface of the piece refinished, and a new hole drilled.

Broken screws or studs are more easily removed than taps because they are nearly always soft enough to permit drilling. Small machine screws can be drilled out by drilling a hole exactly concentric with the axis of the screw, the size of the hole being just under the nominal *minor* diameter of the screw threads, or about two sizes smaller than the tap drill for that size of screw. When done properly the original threads will remain undamaged, but the part of the screw remaining can be easily collapsed inside the hole and the fragments picked out with a scriber. Larger screws are more easily removed by means of left-handed taps and screws, when they are available (which is practically never the case). The screw is drilled, tapped, and fitted with a left-handed screw of about half the diameter of the screw to be removed. Continued turning in a counterclockwise direction will firmly seat and jam the left-handed screw, which in turn will back out the original screw—provided, of course, the left-handed screw does not also break off. Allowing the broken screw to soak in penetrating oil (a mixture of kerosene and a small amount of lube oil) overnight prior to any attempt at removal is an excellent idea if time permits. A special screw extractor (see 3.42, fig. 19) operates on the same principle but is considerably better than the left-handed taps. These screw extractors (called "Easy Out" by one manufacturer) are made of an extremely tough alloy, and act as both left-handed tap and screw, as can be seen in the illustration. They are tapered so that they will grip harder as the force is increased, and also to enable one size of extractor to be used for several sizes of screws.

Dies.

These are instruments for cutting external threads. The type most commonly used by radiomen are variously referred to as "adjustable round split dies," "button dies," or "screw plates," and are illustrated in 3.38 and 3.39, figure 19. Although they are available in a variety of different over-all outside diameters, the Navy has standardized on dies of $\frac{13}{16}$-inch diameter for cutting all standard NC and NF machine screw threads, and dies of 1½-inch outside diameter for cutting all standard NC and NF threads from ¼ inch to $5/8$ inch in diameter. These dies are adjustable within narrow limits by being split at one edge and spring tempered at the opposite edge, the die being compressed into proper adjustment by means of set screws in the stock. Both dies illustrated are identical in all respects except that one of them (3.39, fig. 19) has a refinement in the form of a set screw which automatically limits the amount it can be compressed by the stock to a setting which has been previously made. These dies must be held in a "stock" (see 3.36, fig. 19) in order to be used, and they are secured against rotating inside the stock by means of a cone-pointed set screw which enters into the "split" of the die. Stocks are usually provided with two additional set screws which are used to compress the die into proper adjustment, and the points where these screws are supposed to bear on the edge of the die are usually dimpled. Examination of the die will reveal that one side has the threads champhered for a short distance to facilitate starting, and this side is referred to as the "face" of the die. Dies should be dropped into the stock with the face up, and should be started on the work face first. In adjusting these screw plates, they should be first set for an oversized thread, a few threads cut, the die backed off the work, and then the resulting threads tested for size with a nut. This procedure should be repeated several times over the same few threads, each time compressing the die very slightly to reduce the diameter of the threads until the proper fit is obtained. The die should *never* be adjusted while on the work, but should be backed all the way off before tightening the set screws. The actual operation of threading is in all respects the same as in tapping, and the same precautions must be observed. The same lubricants may be used, that is, lard oil or lube oil for mild steel or drill rod, and turpentine or kerosene for very soft gummy metals. Brass is threaded more easily when dry. Just as it is very important to use the proper size tap drill when tapping, it is important to obtain the proper size rod when threading. The rod must be exactly the same diameter as the nominal *major* diameter of the threads being cut. The rod should be clamped rigidly in a vise, a piece of emery cloth (grit side toward the rod) being of great advantage in eliminating twisting and damage to the surface of the rod. Threading is somewhat less tedious than tapping because the larger clearance of dies greatly reduces jamming.

A complete set of taps and button dies for cutting machine screw threads is shown in 3.44, figure 19. These complete sets are not normally furnished in the Navy, although any taps and dies which are actually required for constant use may be obtained separately.

Some bolt dies and pipe dies are not adjustable, and are made up like the "solid square bolt die" illustrated in 3.41, figure 19. Pipe dies are usually adjustable, however, and have separately inserted and individually adjustable cutters mounted in the stock.

The "rethreading die" or "rethreading nut" illustrated in 3.40, figure 19, cannot be used for cutting initial threads, but is an excellent die for cleaning up damaged threads. They are turned by means of an ordinary wrench. Rethreading dies are precision tools which cut threads more accurately than any of the dies just mentioned, and are therefore often used to "chase" over new threads which have deliberately been cut slightly oversize.

CHAPTER 4. HACKSAWS

TYPES AND USE

1. The following should be observed in the use of hand-operated hacksaws:

(*a*) The blade should be inserted in the frame with teeth pointing away from the operator.

(*b*) Keep blade strained tightly between the frame holding pins, and adjust so there will be no twist.

(*c*) On the forward stroke, bear down sufficiently to stop saw from merely sliding over the work, as this glazes the cutting edge and dulls the saw.

(*d*) Lift the saw on the return stroke, thereby preventing undue rubbing and quick dulling.

(*e*) About 40 strokes per minute is satisfactory for general work—faster cutting than this draws the hardness and destroys the efficiency of the blades.

2. There are two kinds of hacksaw blades, flexible and hard. In the flexible blades, only the teeth are hardened. In the case of hard blades, commonly called "all hard" blades, the hardening process is evenly applied to the entire blade. Most electricians and machinists prefer flexible blades due to their ability to stand considerably more abuse without breaking (the hard blades being brittle like glass).

3. Hacksaw blades are manufactured with different numbers of teeth per inch, depending on the work they are to be used for. The Navy usually uses hacksaw blades with 14, 18, 24, or 32 teeth per inch, and 12 inches long. Blades are also manufactured in other lengths, 8- and 10-inch blades being the most common.

4. The correct and incorrect use of hacksaw blades is partially illustrated in figure 20.

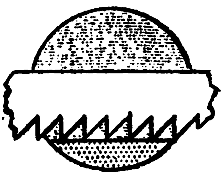
5. In addition to power- and hand-operated hacksaws there are other styles of metal cutting saws. One bears a physical resemblance to a carpenter's crosscut saw for wood working, except that the metal cutting saw is only about two-thirds as large. Then there is a small type of metal cutting saw with triangular frame employing blades 6 to 8 inches in length and with exceedingly fine teeth. This saw is ideal for cross cutting very thin metal sheet, and also for cutting circles.

The blade is about $\frac{5}{16}$ inch wide and can be made to cut a circle much the same as the scroll saw used in woodworking. The last two saws are merely known as "metal cutting saws." There are other types of power metal saws that are quite common, such as the "circular" and "band" types. In every instance, where metal cutting saws are used, thought and care must be given to rules set forth herein, as to "teeth-per-inch" of the blade, cutting pressure, and cutting speeds for the particular grade of work involved.

HACKSAW BLADES

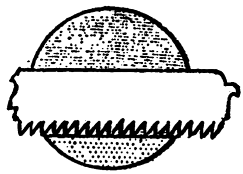
The greatest economy is obtained by selecting the correct pitch.

CORRECT | **INCORRECT**

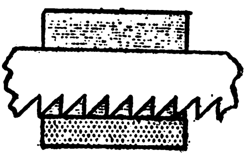


Plenty of chip clearance

14 teeth per inch. For mild material, large sections

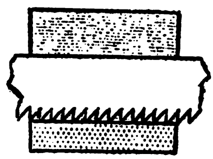


Fine pitch; no chip clearance, teeth clogged

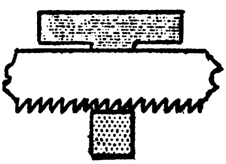


Plenty of chip clearance

18 teeth per inch. For tool steel, high-carbon and high-speed steel

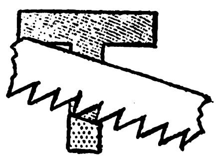


Fine pitch; no chip clearance teeth clogged

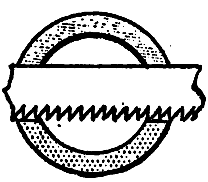


Two teeth and more on section

24 teeth per inch. For angle iron, brass, copper, iron pipe, etc.

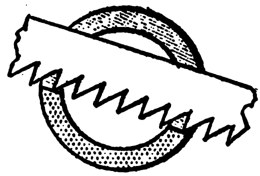


Coarse pitch straddles work stripping teeth



Two or more teeth on section

32 teeth per inch. For conduit and other thin tubing. Sheet metal work



Coarse pitch, straddles work

For general all round work in hand frames, use 18 teeth per inch.

FIGURE 20.

POWER-OPERATED HACKSAWS

In general, the requirements for operating power-driven hacksaws are similar to the requirements for hand-operated hacksaws, especially with regard to character of material being cut, number of teeth per inch in the blade, observance of right degree of pressure on cutting stroke, and "lift" or release of pressure on "back stroke." In addition, the following points of information apply to power-operated hacksaws:

The blade is inserted in the frame with teeth pointing *toward* the power machine. The reason for this is that the cutting stroke must be a "pulling stroke," which tends to keep the blade in the straightest possible line, whereas, if the cutting stroke on a power saw were "pushed" there would be a decided tendency for the blade to buckle and chatter, resulting in broken teeth and quick breakage of the saw. This is true even where heavy and strong frames are used. An adjustable weight is usually installed on the outboard end of the frame, with which to properly gage cutting pressure.

Inasmuch as power-operated hacksaws are mostly used where the stock to be cut is large and often unusually hard, the blades manufactured for such use are generally made of "high-speed steel" or "tungsten alloy steel," and are supplied in lengths ranging from 10 to 24 inches.

Cutting speeds for power hacksaws may be approximately gaged as follows:

(*a*) If cutting *dry* on light machine, run 50 strokes per minute.

(*b*) When cutting compounds are used in the case of medium and heavy machines, 100 strokes per minute give best results in cutting soft steel and wrought iron. 75 to 85 strokes, with same cutting compound, machine and blade, would be satisfactory on tool steel, or annealed steel.

In all cases, whether for hand- or power-operated hacksaws, the work, or material being cut, should be securely held in a vise. Power saws are equipped with a vise for this purpose.

It will be noted in many of the hacksaws smaller blades and other metal cutting saw blades there is a slight wavy effect along the row of teeth—the waves occuring from one to four times per inch. This has no intended purpose, but an accumulative buckling effect on that edge of the blade having the teeth, and results from the process of cutting, staggering, and hardening the teeth. In other words, this latter process has tended to increase the length of the cutting edge over the length of the back edge of the blade.

QUESTIONS

1. How should the blade be inserted in the frame of a hand-operated hacksaw? Why?

2. How should the blade be inserted in the frame of a power operated hacksaw? Why?
3. Why must the blade be tightly strained?
4. What limits the cutting speed?
5. Why are flexible blades preferable to hard blades?
6. Explain the construction of the flexible blade.
7. How are hacksaw blades classified?
8. What blades are usually encountered in the Navy?
9. What is meant by pitch of teeth?
10. What blade is best suited for soft material? Thin edges? Metal tubing? Tool steel?
11. What blade is generally used for all-around work?
12. Besides the common hacksaw, what other metal cutting saws are in common use?
13. How do power saw requirements differ from hand saw requirements?

CHAPTER 5. SCREWS AND FASTENINGS

MACHINE SCREWS

General.

The term "machine screws" is the general commercial term for screws to be driven into drilled and tapped holes in the assembly of metal parts. When furnished with a nut the combination is referred to as a "bolt." Machine screws are regularly made in steel and brass, with a variety of styles of heads and finishes. The complete description of a machine screw must include, and in the following order, the *length* in inches, a description of the *thread*, shape of *head*, *material* from which made, special *finish* (when appropriate), and the type of *drive* employed (if other than "slotted"). The following example gives the proper description of a typical size of screw as used in the assembly of radio apparatus: "One-half inch, eight-thirty-two, binding head, brass, chromium plated (bright), "Phillips" recessed head, machine screws."

Length.

The nominal length of a machine screw may include none, a part, or all of the head of the screw as shown in the illustration in the center of figure 21. It will be noted that only the part of the head that remains below the surface of the work is included in the nominal length of the screw.

Threads.

A description of the threads of a screw includes first the diameter and then the pitch. Machine screws are seldom made in sizes larger than ¼ inch in diameter, the diameters then being expressed in fractions of an inch. The diameters of machine screws smaller than 1/4 inch are designated in gage numbers of the American Screw Gage, the dimensions of which are shown in figure 22. Note that the screw gage is entirely different than any other gage, and has nothing in common with the American (B & S) Wire Gage or the gage used in determining the diameters of wire twist drills. The gage number refers to the *major* diameter of the threads, which will be the same as the nominal diameter of the stock from which the threads were cut. In order to determine the diameter of a screw in gage number, it is necessary to use a screw gage made for this purpose, or to measure the major diameter by means of a micrometer or other means, and then obtain the gage number by referring to a table of the American Screw Gage. Any of the several wire or sheet metal gages will serve in the absence of a micrometer providing the gage at hand is stamped with the actual decimal equivalents of that particular gage. In this case the gage is used only to obtain the approximate nominal major diameter of the threads, the actual American Screw Gage number then being obtained from a table like that in figure 22.

The pitch, or number of threads per inch of screw length, may be determined with an ordinary steel rule by counting the number of threads in an inch of screw length, or it can be determined more conveniently by comparison with a screw pitch gage as illustrated in figure 23. The gage consists of a jack-knife style of case containing a quantity of blades, each blade having a different number of teeth per inch along its edge. Different blades are tried until one is found which will exactly match the profile of the threads under question, the pitch then being obtained from the number stamped on that particular blade.

Several more or less standard and generally accepted series of threads have been used in the past, notably the USS, SAE, and ASME series, all employing a 60° V-type of thread but differing in the number of threads per inch for a given size of screw, and all having both standard and special sizes for specific uses. This multitude of screw systems was greatly simplified recently when Congress combined all three into an American National Standard Form of threads, consisting of two series known as the "National Coarse" Thread Series (abbreviated "NC") and the "National Fine" ("NF") Thread Series, these two series to hereafter be used *for all purposes*. In general, the USS threads became the NC, and the SAE became the NF series, whereas both the NC and NF series of machine screws were taken largely (but not entirely) from the former ASME system. One may occasionally hear reference made to USS or SAE standards, but this practice should be discouraged as the terms are now obsolete. Likewise, thread sizes which appeared in the old standards but which do not appear in the new NC and NF series should not be used for any purpose. A table of the dimensions of the new series appears in figure 22.

The coarse thread (NC) series is preferred for all general use where extreme strength is not required. NC machine screws are used exclusively in the fabrication of radio apparatus. Fine threads are used only in the assembly of precision machinery, automobile engines, aircraft, etc.

When describing a thread, the diameter is given first, and may be stated as a gage number or given in inches. This is followed by the number of threads per inch. Thus a "six-thirty-two" screw (written 6–32) indicates a screw cut from No. 6 A. S. G. wire, and having 32 threads per inch of screw length, regardless of the actual length of the screw. Note particularly that "six" and "thirty-two" are two separate numbers which indicate two separate measurements, and are *never* to be written 6/32 or pronounced "six-thirty-seconds" as a fraction. However, a "quarter-twenty" screw (written ¼″–20) is ¼ inch in diameter and has 20 threads per inch.

Heads.

All screw manufacturers list flat, round, and oval heads as standard stock items, and some also include fillister, binding, or other types. Standard types of heads are illustrated in figure 21 (center).

Round heads are used universally by the casual buyer, but binding heads are used by the discriminating manufacturer for several obvious reasons. The binding head is considerably larger in diameter, making it possible to use much larger clearance holes in metal parts thereby insuring very free and easy fitting of parts. The head is lower, thereby improving appearance and reducing the possibility of catching on clothing, etc. Binding head screws take a larger screwdriver and, due to the flatter curvature of the head, the driver will cling more tightly with less chance of slipping. Binding heads are used for securing wires at the terminals of electrical fixtures and terminal strips. Round heads have been in common use for so long that it will probably be some time yet before the corner hardware store (and the Navy Supply Department) discontinue the stocking of round in favor of binding head screws in spite of their admitted superiority and preference.

Flat heads are used when it is desired to countersink the entire head below the surface of the work, but are not considered primarily as being an ornamental type of head. The oval head, on the other hand, is an ornamental head to give a finished appearance to hardware, escutcheon plates, etc., and further to present a smooth surface that will not catch on the clothing or interfere with routine cleaning. Fillister heads are sometimes used as ornamental heads, but this practice should be discouraged because they are too small in diameter to permit free fitting clearance holes, and project out from the work where they catch on things, and are very difficult to keep clean. Fillister heads are primarily intended to be used as cap screws in the assembly of extremely accurate jigs, dies, or machine parts where the entire head is to be countersunk below the surface in a cylindrical hole cut by a counterbore. The only time fillister heads are used on the surface is when they have a small transverse hole drilled through the head to receive a "safety wire," which prevents their working loose due to vibration as in aircraft.

There are many special heads in use, a few of them being illustrated at the top of figure 21. Te washer head is stocked as standard by some companies, and is often used as a binding head for attaching wires to the terminals of electrical fixtures, terminal strips, etc. The hex and hex-washer heads are very common for sheet metal screws because they can be driven by means of a powered socket wrench.

Materials.

Machine screws are regularly manufactured in steel and brass, and can be obtained in most any material on special order. Certain companies specialize and list as standard stock items screw products made of special metals, such as 17–ST Dural for use in aircraft, and "stainless" steel for use in chemical or food containers. Steel screws are somewhat stronger, considerably cheaper, but more subject to corrosion than brass. Steel screws are never used in the fabrication of good radio apparatus because they are apt to rust and "freeze" into the holes to such an extent that they break off when an attempt is made to remove them. A gross of ½ inch 8–32 brass machine screws will cost about $1.10, but the same screws made of steel would be only about 40 cents. Either could be obtained from stock in nickel plated finish for about 6 cents additional per gross.

Special Finishes.

Unless specified otherwise, machine screws are regularly furnished in plain bare metal. Electroplating and other finishes are ordinarily applied either to prevent rust and corrosion, or to enhance the appearance. The most frequenty used special finishes are characterized as follows:

Rust-resistant.—"Parkerized"—and excellent finish for rust resistance, dull satin black in color, wears fairly well and makes a good base for paint. "Hot galvanized"—an excellent rust resistant gray finish for wood crews, but inadvisable for small machine screws due to the thickness of the zinc coating on the threads. "Electro-galvanized"—gray colored zinc coating with good rust resistance.

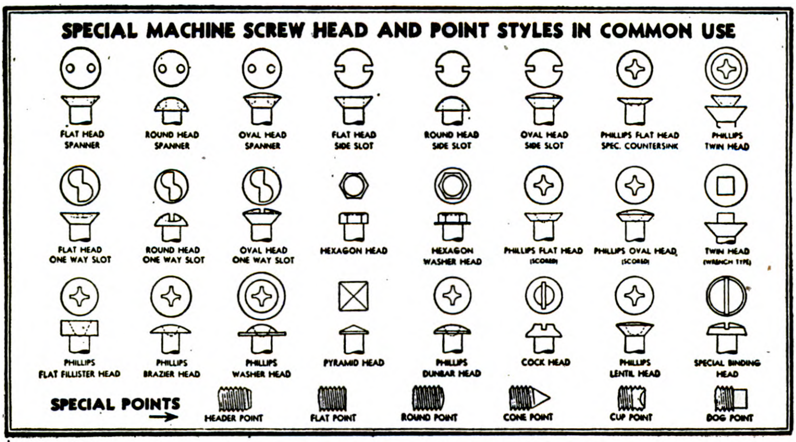
Rust resistant and decorative.—"Nickel plated"—a good rust resistant available in either dull or bright finish. Good quality high lustre plating requires that the screw heads be first ground and polished, a process that is quite expensive, and may run as high as $1 extra per gross. "Chromium plate"—most excellent rust resistant and wear resistant finish in brilliant blue-white satin, or with ground and polished heads, a brilliant polished finish. "Cadmium plated"—a lusterous silver-gray finish in wide use, with excellent rust resistance but very poor wearing qualities. Cadmium plating is employed on parts that will not receive any handling which would wear off the plating, such as inside of a piece of radio apparatus.

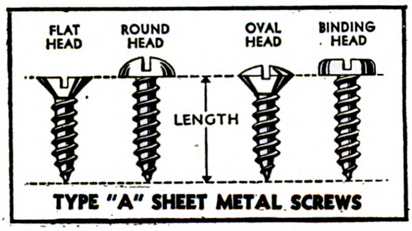
Decorative only (*not rust resistant*).—"Blue steel"—a clean brilliant blue color without scale. "Japanned"—a thin, black enamelled finish available in either dull or glossy.

Drive

By far the most common method of driving machine screws is by means of a slot milled into the head of the screw, such screws being referred to as "slotted-head" screws. Several departures from this method have appeared from time to time for special purposes, mostly in production. By using a hexagonal head it is possible to put pressure on the driver (in this case a socket wrench) without upsetting the screw or danger of the driver slipping and marring the work or cutting the operator's hands. This method was so successful that it was becoming almost universally used in the case of sheet metal or self-tapping screws for metal or plastics in production, until it was finally abandoned in favor of the infinitely superior Phillips *recessed head* screws introduced recently by the American Screw Co. Some 20 of our country's leading screw manufacturers now offer any of their products with the Phillips recessed head, which has so many advantages in its favor that it met with instant and unwavering success. A single trial will convince even the most stubborn that this method of drive should certainly be accepted for universal use, and the manufacture of slotted head screws discontinued. Many manufacturers have already shifted over to Phillips screws exclusively, and we, as casual buyers, can help the trend by doing likewise. The "recess" in the screw head is tapered in such a manner that one driver will fit perfectly as many as five different sizes of screws, the taper feature insuring such a tight fit that the screw will actually cling to the driver. The taper further makes the screw "self-centering" so that it is unnecessary to use a hand to guide the screw, a property brought out very strikingly in the case of starting wood screws. The screw clings to the driver and lines up so perfectly that it feels like the threads are actually on the screwdriver itself. It is impossible for the driver to slip out of the screw, or for the screw to "upset," and the driving may all be done

640821°—45——4

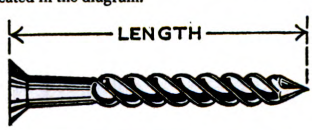




DRIVE SCREWS

Drive Screws are regularly made in steel only, with the one style of head illustrated. They are driven with a hammer like nails, and are recommended for all uses where a holding power greater than that of nails, yet not as great as that of screws, is required. The head is slotted or recessed for withdrawal, when desired.

Drive Screw sizes are designated by length in inches and by diameter in numbers of the American Screw Gauge. The length measurement includes the head as indicated in the diagram.



PHILLIPS SCREWDRIVERS:

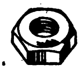
USE THE RIGHT DRIVER FOR THE JOB

Driver Size	Corresponding Wood Screw Sizes
No. 1	Nos. 2, 3, 4
No. 2	Nos. 5, 6, 7, 8, 9
No. 3	Nos. 10, 11, 12, 14, 16
No. 4	Nos. 18, 20, 24.

Same Relative Sizes in Machine, Sheet Metal Screws

FIGURE 21.

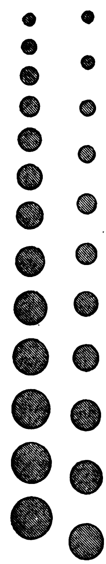
MACHINE SCREW NUTS

HEXAGON	SQUARE
	
Chamfered One Side	Not Chamfered

Screw Diam.	Threads per Inch Coarse	Threads per Inch Fine	Width Across Flats		Thickness	
2	56	64	3/16	.187	1/16	.066
3	48	56	3/16	.187	1/16	.066
4	40	48	1/4	.250	3/32	.098
6	32	40	5/16	.312	7/64	.114
8	32	36	11/32	.343	1/8	.130
10	24	32	3/8	.375	1/8	.130
12	24	28	7/16	.437	5/32	.161
1/4	20	28	7/16	.437	3/16	.193
5/16	18	24	9/16	.562	7/32	.225
3/8	16	24	5/8	.625	1/4	.257

COMPARISON OF GAUGES

SCREW GAUGE (AMERICAN SCREW GAUGE) No.	Inch
0	.060
1	.073
2	.086
3	.099
4	.112
5	.125
6	.138
7	.151
8	.164
9	.177
10	.190
11	.203
12	.216



RIVET GAUGE (OLD STANDARD BIRMINGHAM WIRE GAUGE) No.	Inch
17	.058
16	.065
15	.072
14	.083
13	.095
12	.109
11	.120
10	.134
9	.148
8	.165
7	.180

MACHINE SCREWS:

DIMENSIONS OF THREADS IN INCHES

COARSE THREAD SERIES

Diam.	Threads per inch	Major Diam. Max.	Major Diam. Min.	Pitch Diam. Max.	Pitch Diam. Min.	Minor Diam. Max.	Minor Diam. Min.
2	56	.0860	.0820	.0744	.0724	.0641	.0608
3	48	.0990	.0946	.0855	.0833	.0734	.0697
4	40	.1120	.1072	.0958	.0934	.0813	.0771
5	40	.1250	.1202	.1088	.1064	.0943	.0901
6	32	.1380	.1326	.1177	.1150	.0997	.0947
8	32	.1640	.1586	.1437	.1410	.1257	.1207
10	24	.1900	.1834	.1629	.1596	.1389	.1326
12	24	.2160	.2094	.1889	.1856	.1649	.1586
1/4	20	.2500	.2428	.2175	.2139	.1887	.1814
5/16	18	.3125	.3043	.2764	.2723	.2443	.2362
3/8	16	.3750	.3660	.3344	.3299	.2983	.2893
7/16	14	.4375	.4277	.3911	.3862	.3499	.3398
1/2	13	.5000	.4896	.4500	.4448	.4056	.3948

FINE THREAD SERIES

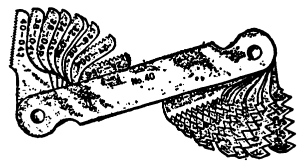
Diam.	Threads per inch	Major Diam. Max.	Major Diam. Min.	Pitch Diam. Max.	Pitch Diam. Min.	Minor Diam. Max.	Minor Diam. Min.
2	64	.0860	.0822	.0759	.0740	.0668	.0638
3	56	.0990	.0950	.0874	.0854	.0771	.0738
4	48	.1120	.1076	.0985	.0963	.0864	.0827
5	44	.1250	.1204	.1102	.1079	.0971	.0931
6	40	.1380	.1332	.1218	.1194	.1073	.1031
8	36	.1640	.1590	.1460	.1435	.1299	.1254
10	32	.1900	.1846	.1697	.1670	.1517	.1467
12	28	.2160	.2098	.1928	.1897	.1722	.1665
1/4	28	.2500	.2438	.2268	.2237	.2062	.2005
5/16	24	.3125	.3059	.2854	.2821	.2614	.2551
3/8	24	.3750	.3684	.3479	.3446	.3239	.3176
7/16	20	.4375	.4303	.4050	.4014	.3762	.3689
1/2	20	.5000	.4928	.4675	.4639	.4387	.4314

Thread is 60° V-form, flattened top and bottom one-eighth its height. American Machine Screws conform in technical detail to U. S. Government Master Specification No. 548, and to the requirements of the American Standards Association.

FIGURE 22.

Tap Drill Sizes

Size	Threads per Inch NC	Threads per Inch NF	Threads per Inch NS	Outside Diameter Inches	Tap Drill Approx. 75% Full Thread
0	....	80	....	.0600	3/64"
1	....	....	56	.0730	54
1	64	....	....	.0730	53
1	....	72	....	.0730	53
2	56	....	....	.0860	50
2	....	64	....	.0860	49
3	48	....	....	.0990	47
3	....	56	....	.0990	45
4	....	....	32	.1120	45
4	....	....	36	.1120	44
4	40	....	....	.1120	43
4	....	48	....	.1120	42
5	....	....	36	.1250	40
5	40	....	....	.1250	38
5	....	44	....	.1250	37
6	32	....	....	.1380	35
6	....	....	36	.1380	34
6	....	40	....	.1380	33
8	....	....	30	.1640	30
8	32	....	....	.1640	29
8	....	36	....	.1640	29
8	....	....	40	.1640	28
10	24	....	....	.1900	25
10	....	....	28	.1900	23
10	....	....	30	.1900	22
10	....	32	....	.1900	21
12	24	....	....	.2160	16
12	....	28	....	.2160	14
12	....	....	32	.2160	13
1/4	20	....	....	.2500	7
1/4	....	28	....	.2500	3
5/16	18	....	....	.3125	F
5/16	....	24	....	.3125	I
3/8	16	....	....	.3750	5/16"
3/8	....	24	....	.3750	Q
7/16	14	....	....	.4375	U
7/16	....	20	....	.4375	25/64"
1/2	13	....	....	.5000	27/64"
1/2	....	20	....	.5000	29/64"



Screw Pitch Gage.

WOOD SCREWS

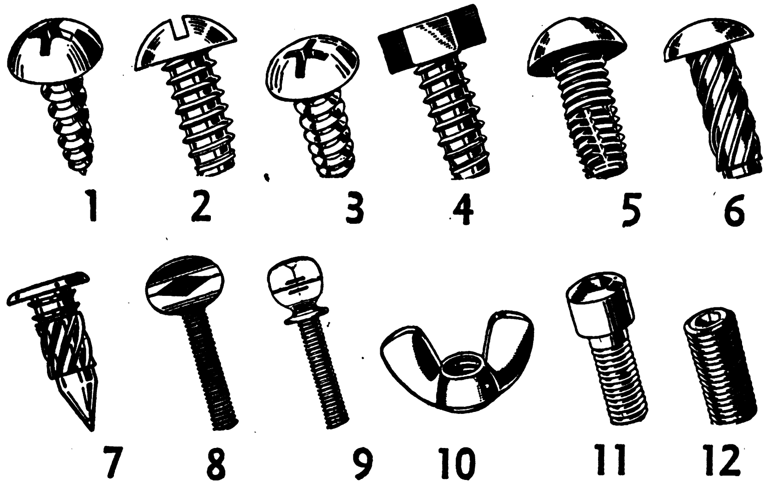
BIT SIZES FOR BORING PILOT HOLES AND SHANK CLEARANCE HOLES (For Slotted Head Screws)

(★ Starred figures indicate bit sizes for AMERICAN **PLUS** SCREWS with the patented Phillips Recessed Head)

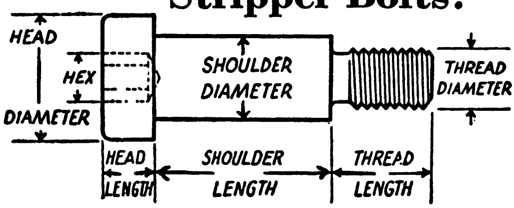
No. of SCREW	BIT or DRILL SIZES — FOR SHANK CLEARANCE HOLES — TWIST BIT (Nearest size in fractions of an inch) Slotted & Phillips	FOR SHANK CLEARANCE HOLES — DRILL Gauge No. or Letter To be used for maximum holding power Slotted & Phillips	FOR PILOT HOLES* — HARD WOODS — TWIST BIT (Nearest size in fractions of an inch) Slotted	HARD WOODS — TWIST BIT Phillips	HARD WOODS — DRILL Gauge No. To be used for maximum holding power Slotted	HARD WOODS — DRILL Phillips	SOFT WOODS — TWIST BIT (Nearest size in fractions of an inch) Slotted	SOFT WOODS — TWIST BIT Phillips	SOFT WOODS — DRILL Gauge No. To be used for maximum holding power Slotted	SOFT WOODS — DRILL Phillips	No. of AUGER BIT to counter-bore for sinking head (by 16ths) Slotted & Phillips
0	1/16	52	1/32	—	70	—	1/64	—	75	—	—
1	5/64	47	1/32	—	66	—	1/32	—	71	—	—
2	3/32	42	3/64	★1/32	56	★70	1/32	★1/64	65	★75	3
3	7/64	37	1/16	★1/32	54	★66	3/64	★1/32	58	★71	4
4	7/64	32	1/16	★3/64	52	★56	3/64	★1/32	55	★65	4
5	1/8	30	5/64	★1/16	49	★54	1/16	★3/64	53	★58	4
6	9/64	27	5/64	★1/16	47	★52	1/16	★3/64	52	★55	5
7	5/32	22	3/32	★5/64	44	★49	1/16	★3/64	51	★53	5
8	11/64	18	3/32	★5/64	40	★47	5/64	★1/16	48	★52	6
9	3/16	14	7/64	★3/32	37	★44	5/64	★1/16	45	★51	6
10	3/16	10	7/64	★3/32	33	★40	3/32	★5/64	43	★48	6
11	13/64	4	1/8	★7/64	31	★37	3/32	★5/64	40	★45	7
12	7/32	2	1/8	★7/64	30	★33	7/64	★3/32	38	★43	7
14	1/4	D	9/64	★1/8	25	★31	7/64	★3/32	32	★40	8
16	17/64	I	5/32	★1/8	18	★30	9/64	★7/64	29	★38	9
18	19/64	N	3/16	★9/64	13	★25	9/64	★7/64	26	★32	10
20	21/64	P	13/64	★5/32	4	★18	11/64	★9/64	19	★29	11
24	3/8	V	7/32	★3/16	1	★13	3/16	★9/64	15	★26	12

*Sometimes called "Ancher Holes"

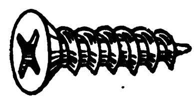
FIGURE 23.



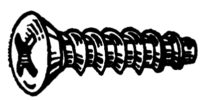
Stripper Bolts:



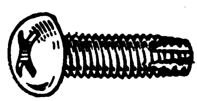
Sheet Metal Screws:



Type A

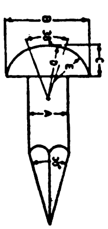


Type Z



Self-Tapping

DIMENSIONS OF ESCUTCHEON PINS:



A = Body Dia.
B = 2A
C = ¾A
D = 1.335A
E = .867A

Head semi-elliptical in axial cross-section

No.	A	B
10	.134	.268
11	.120	.240
12	.109	.218
13	.095	.190
14	.083	.166
15	.072	.144
16	.065	.130
17	.058	.116
18	.049	.098
19	.042	.084
20	.035	.070
21	.032	.064
22	.028	.056

STOVE BOLT

Figure 24.

with one hand, which leaves the other hand free to hold the work. The heads are much stronger, because the outer rim of the head is not cut as in the case of the slotted screw, and they are also very much neater in appearance. They cost the same as slotted head screws, and the drivers are actually cheaper because fewer sizes are needed (two sizes, Nos. 2 and 3, fit all machine screws ordinarily used in Navy transmitter or receivers) and each driver lasts much longer because of the perfect fit and absence of friction and slipping of the driver in the recess. The Phillips recessed head feature can be incorporated into any screw regardless of the shape of the head, and can even be used with set screws which have no heads at all.

Other special drives include the "spanner" and "side-slot," which can be installed easily by the manufacturer with his special tools, but are difficult for the "tinkerer" to remove without leaving evidence of tampering. The "one-way slot" allows driving and tightening, but not withdrawal, and is used to retain hardware in public buildings, etc.

Cap Screws.

Cap screws are similar to machine screws in that they are also primarily intended to be driven into drilled and tapped holes. The dividing line between the two screws is not very clearly defined, but in general the machine screw is smaller than ¼ inch and is driven with a screwdriver, whereas the cap screw is larger and is driven with a wrench or key. Cap screws are made to closer tolerances than are machine screws, and are standard only in the NF thread series although NC threads may be obtained on special order. Cap screws with hexagonal heads have a very thin and accurately faced washer surface under the heads to insure a precision fit with the work. They are usually made of high alloy steel, and may be obtained fully hardened.

Cap screws that are used in the assembly of expensive machinery, accurate dies, etc., almost invariably have hollow heads that are driven by means of a key, and are of the Allen or the Bristo pattern, a comparison of which appears in figure 23. The Allen type of socket head may have any external shape, but the socket itself is hexagonal in shape and is cold-forged into the head. Socket head screws are driven by means of a key which just fits into the socket. An Allen cap screw is illustrated as No. 11, figure 24. The outside shape of the head is the standard fillister type, which is to be countersunk into a cylindrical hole which has been cut by means of a counterbore. Bristo sockets are round instead of hexagonal in shape, and have several "splines" which engage with the key for driving. Both types are in general use, and both are quite standard, although each type has certain advantages over the other for specific uses. The

Allen hex-sockets are to be preferred (and their exclusive use encouraged) for screws having threads of 1/4 inch in diameter and larger, unless the screw is made of aluminum or other soft metal. Similarly, the Bristo multiple-spline sockets are infinitely superior to the hex-sockets in screws having threads smaller than 1/4 inch in diameter, and also in the special case where the screw is made of any metal which is softer than steel. The multiple-spline Bristo key transmits only turning forces to the screw, and slight variations in fit are of no particular consequence. In the hex-socket, however, twisting of the hex-key will transmit considerable expanding pressure on the walls of the screw, which becomes more serious as the relative clearance between socket and key is increased, and with sufficient clearance (such as would be caused by any expansion of the screw) the key will slip inside the socket instead of turning the screw. This is not serious except in the case of small screws or screws made of soft metals, and the Allen hex-socket screws are still preferred for all larger sizes due to their neater appearance, and because of the fact that accumulations of paint or dirt may be removed more easily for inserting the key. Many large users of socket-head screws will adhere to one type exclusively, but the trend is more and more toward Allen for the larger sizes and Bristo for small screws, and for screws made of soft metal.

STRIPPER BOLTS

These are exactly the same as cap screws, except that they have a very accurately ground and polished shoulder, and are used in the assembly of machinery as fulcrums for levers, or shafts for gears, cams, etc. The illustration in figure 24 (center), shows the dimensions of a stripper bolt with Allen socket head, although they are also available in Bristo as well as the common hexagonal bolt head. NF threads only are standard as in the case of cap screws.

MACHINE BOLTS

These are inexpensive commercial fastenings, similar to machine screws but in larger sizes and made up with square or hex heads. National coarse threads are standard, and may be either rolled or cut, although rolled threads are preferred because of their great saving in cost and their slight increase in strength. Machine bolts are regularly furnished with nuts assembled on them, and are usually finished in a dull black.

CARRIAGE BOLTS

Carriage bolts are quite similar to machine bolts except that they have "brazier" or "dunbar" shaped heads with a square shank extending below the head a sufficient distance to keep the screw from turning when it is hammered into a hole drilled in wood. They have the same "black iron" finish as machine bolts, and come with square nuts assembled on them. They are used for all general applications of bolts for wood, but have been used elsewhere occasionally where the square nonturning shank is desirable.

STOVE BOLTS

Stove bolts are extremely cheap fastenings that are used as a substitute for machine screws in certain applications where the expense and accuracy of machine screws is unnecessary. They are available in round, flat, and "oven" (similar to "brazier") heads, and may be either slotted or have the Phillips recessed heads. Stove bolts have special coarse threads that *do not* conform to the National Standard form of threads, the nominal major thread diameters being expressed in fractions of an inch. A stove bolt with the "oven" type of head is illustrated in the center of plate B.

SHEET METAL SCREWS

There are two more or less standard types of sheet metal screws manufactured by several concerns, known universally as type A and type Z. Both types are identical inasmuch as they are made of extremely hard steel, have very sharp threads, are very expensive, and are available in the same lengths, diameters, and head styles as are machine screws. They are driven into punched or drilled pilot holes in sheet metal, fibre, hard rubber, plastics, etc., by means of a screwdriver, and in many cases serve where screws, bolts, or rivets were previously required. The type A has very coarse threads and at first glance appears somewhat like a wood screw, as may be seen in the illustrations of this type in figure 21. The type Z is very similar but is somewhat stronger due to the use of a finer thread, thus permitting its use in heavier gages of metal. Both types are often referred to as "self-tapping" screws, although this is not strictly the case inasmuch as the threads are formed by embossing the work rather than actually removing chips of metal as is done when using a regular tap. It is much better to refer to these screws as "sheet-metal" screws.

SELF-TAPPING SCREWS

There are, however, several companies who produce a truly self-tapping screw, illustrated as No. 3.33, figure 19. Screws of this type have standard NC machine screw threads, and can actually be replaced by a standard machine screw of corresponding size. They differ from common sheet metal screws in that the end of the screw is fluted just like a regular tap, the flutes forming cutting edges which remove chips from the material being tapped. The best screws of this type available are manufactured by the Shakeproof Lock Washer Co., and a similar product is produced by the Parker-Kalon Co. The type C sheet metal screws of the American Screw Co. (called "self-tapping" by them) have the standard NC threads, but are not of the thread cutting type. The Parker-Kalon self-tapping screw is shown at No. 5, figure 24.

DRIVE SCREWS

These are similar to the common sheet-metal screws except that they are meant to be forced into the metal or plastic by means of a press or a common hammer. They are used in large quantities by the trades for attaching escutcheon plates or name plates to iron castings, motors and machinery, plastics, etc., and are simply "nailed" into previously drilled pilot holes. Nos. 6 and 7 at the top of figure 24 illustrate two types produced by Parker-Kalon. Another type of drive screw, illustrated at the bottom of figure 21, is for use in wood only, and is used mostly in the manufacture of furniture and packing boxes.

SET SCREWS

These are used to fasten the hubs of pulleys, wheels, gears, knobs and tuning dials, etc., to shafts, either permanently or semipermanently as required. Large set screws sometimes have square heads which are tightened by means of a wrench, making it necessary that the head protrude beyond the hub. The screws are extremely dangerous and are never installed on high-speed rotating machinery or where they are within reach due to the danger of getting caught on them. Most set screws are of the "headless" type and are obtained in such lengths that they fit flush with the face of the hub and do not protrude. Headless set screws may be slotted so that they may be tightened with a screwdriver, they may have the Phillips recess feature, or they may be of the "hollow" type with either the Allen or Bristo sockets. The hollow type is the most popular, with Bristo sockets perferred in machine-screw sizes and Allen sockets in the larger sizes. Set screws have characteristic points as shown at the top of figure 21, the particular point to use depending upon requirements. The flat or header point is used where frequent resetting or adjustment is required, and will produce a minimum of damage to the shaft, particularly if the shaft has been hardened. The round or oval point is also used where frequent resetting is required, but where a very shallow indexing groove is desired. Cone point screws are used for permanently spotting a pulley or coupling to a shaft, in which case the shaft is drilled to fit the cone point. If the shaft is not hardened, the pilot hole may be drilled somewhat smaller than the minor diameter of the screw threads, the set screw then being jammed into this hole for a good permanent installation. Cone pointed set screws are also often used for pivots in various machinery applications. The cup point unfortunately is by far the most commonly used by manufacturers because it gives a very rapid, easily installed semipermanent installation. Their use has always been frowned upon because they are definitely not permanent and they scar up the shaft so that it is sometimes very difficult to remove the collar or coupling when necessary. The dog point is primarily intended for the same purpose as the cone point, but is very seldom made. The half-dog point is the same diameter as the dog point, but only half as long, and is more widely used. A hole in the shaft that is not larger than the dog is required if play is to be avoided. The half-dog point is often used for applications similar to those described for the flat, header, round, or oval points, and for some applications is actually preferred. For its originally intended use, however, the cone point is probably the better choice and is to be preferred for permanent installations in Navy equipment.

MACHINE SCREW NUTS

Machine screw nuts are made of steel or brass, and are usually hexagonal in shape with dimensions as shown in figure 22. Nickel-plated nuts are often supplied with dimensions much smaller than those shown, and champhered on both sides. Wing nuts, to be tightened without the aid of tools, are available in all standard threads, and are shaped as shown at No. 10, figure 24. A cylindrical nut with the outside knurled is called a thumb nut. Castle-nuts, so named because of their appearance, are regular hex nuts which incorporate a slotted skirt through which the nut is locked to the shaft by cotter pins. After tightening the nut, a cotter pin is passed through a transverse hole in the screw as well as a pair of the slots in the nut, thereby locking the nut against coming loose. Another locking nut, known as the Elastic Stop-Nut, is similar in appearance to the castellated nut just described, except that the skirt on top of the nut is used to crimp a thick fiber washer into place. When the nut is installed, the screw must force its way into the fiber washer against sufficient friction that it remains quite tight. Elastic stop-nuts are very often used in connection with trimmer condensers and other alignment adjustments in radio equipment because they may be easily adjusted but will then stay put without requiring any further special attention. Ornamental nuts, hexagonal at the bottom and with a closed-over hemispherical dome over the top, are called cap nuts. They are usually finished in nickel or chromium plate, and are used where it is desired to hide the front end of a screw for ornamental reasons, such as on the front panel of a radio transmitter or receiver.

ESCUTCHEON PINS

These are made of brass or steel, and are similar to wire brads except for the shape of the heads. They come in all reasonable lengths and in different diameters, which are expressed in gage numbers of the Birmingham (sometimes called "Stub's") iron wire gage, as shown in figure 24. They are furnished standard in round heads only, as illustrated, and are used for nailing name plates or escutcheons to finished wooden objects such as phonograph or broadcast receiver cabinets. They can also be hammered into metal or plastic, provided a very carefully determined size of pilot hole is previously drilled, and they can also be used as small rivets. They are available in all the special ornamental finishes regularly obtainable on hardware.

WOOD SCREWS

General.

Wood screws have many details in common with machine screws, and are available with the same types of standard heads, made from the same metals, and in the same lengths, finishes, drives, etc., as are machine screws. The threads of wood screws are all uniform, making it neither necessary nor desirable to state the number of threads per inch when ordering or describing the screws. They are ordered by diameter only, which is specified in gage numbers of the American Screw Gage in the same manner as for machine screws, with but one exception. Machine screws larger than A. S. G. No. 12 are designated in fractions of an inch, whereas wood screws always employ gage numbers regardless of the diameter. The nominal diameters of the additional larger sizes not appearing in the table at the top of fig. 22 are as follows: No. 14=0.242 inch, No. 16=0.268 inch, No. 18=0.294 inch, No. 20=0.320 inch, and No. 24, the largest,= 0.372 inch.

Wood screws have a so-called "gimlet" point which is more or less self-starting in wood. When they are to be driven into hard wood, or into any wood to a depth greater than the length of the threaded part, it is best to provide a "pilot hole" somewhat smaller than the minor diameter of the threads, and a body clearance hole to allow the unthreaded part of the body to enter the wood without binding. These holes are used to prevent the wood from splitting, or to prevent the screw heads from breaking due to the great force required in driving. When using soft woods, the pilot hole might not be necessary, but both are required in hard woods. In using wood screws with Phillips recessed heads, however, the pilot holes may be made much smaller in hard wood and they are entirely unnecessary in soft wood. This is because the screw head is much stronger, and is able to withstand the tremendous pressure without breaking, and also because the screw head clings to the driver without any tendency to slip or deform the head. A table of wood screw pilot and body clearance drill sizes appears in figure 23.

LAG SCREWS

Very large wood screws with square heads to be turned by means of a wrench are called lag screws. Diameters are specified in fractions of an inch, and they bear the same general relationship with wood screws as do machine bolts with machine screws. Lag screws are standard in black finished steel only, and are used in heavy construction and "hold-down" applications where carriage bolts cannot be used due to inaccessibility of the other end of the screw for attaching the nut.

CHAPTER 6. ANNEALING, BENDING METAL TUBING AND SMALL RODS, FLANGING TUBING, CUTTING SHEET ALUMINUM, CUTTING ROUND HOLES IN ALUMINUM, BEARING PULLER FOR SMALL BEARINGS, SPARK TEST FOR HARDNESS OF METALS

ANNEALING

Annealing is the process of treating metals, glass, etc., by heating and cooling, so as to remove hardness and brittleness.

To Anneal Steel.

Heat to a dull red heat and then remove the metal from the heat and permit it to cool in air.

To Anneal Brass or Copper.

Brass or copper is heated to a *low red heat* and quickly dropped into cold water.

BENDING METAL TUBING AND SMALL RODS

First of all determine the character of the composition of the tube (whether soft or hard copper, bronze, silicon bronze etc.). Many tubes are made by different processes and are finished nearly alike, and you cannot very well determine the procedure to follow when desiring bends or flanges in them. But the file test will quickly make this clear or even the point of a cold chisel will do to determine the nature of the metal.

Bending Small Tubing.

It is well to anneal the tubing first. Then procure several washers and stack them upon one another until the diameter of the tubing is obtained. Two wooden blocks are placed on each side of the washers and are clamped in a vise as shown in figure 25. Then grasp the protruding end of tubing and bend to requirements.

Another plan to secure a uniform bend of smaller tubing is to employ an outside mandrel on the tube. This consists of a close and tightly wound spiral of iron wire of about 14 gage over the tube, as shown in figure 26. This distributes the stresses in the operation of bending, and it can be unwound afterwards. The tubing should be bent on a metal bar held in a vise as shown in figure 27.

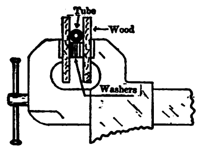


FIGURE 25.

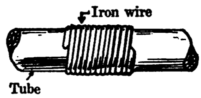


FIGURE 26.

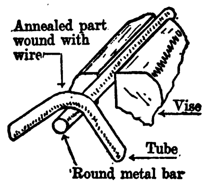


FIGURE 27.

Small bore tubing can be bent by placing a piece of soft copper wire (a fairly good fit) inside, bending the tubing, and withdrawing the wire afterward. A piece of solid wire solder well greased can be used and then melted out.

Copper tubing may be readily flared for attachment of fittings by the use of a pair of lineman's splicing pliers. The end of the tube to be flanged is caught in the jaw of the pliers and a punch or a drift pin is used to press out the mouth of the tubing to the extent required. Ordinarily some one of the grooves in the pliers will be found to fit almost any outer diameter of the copper tubing commonly used. When this is not the case, the grooves of the splicing pliers may be readily enlarged by cutting with an emery wheel.

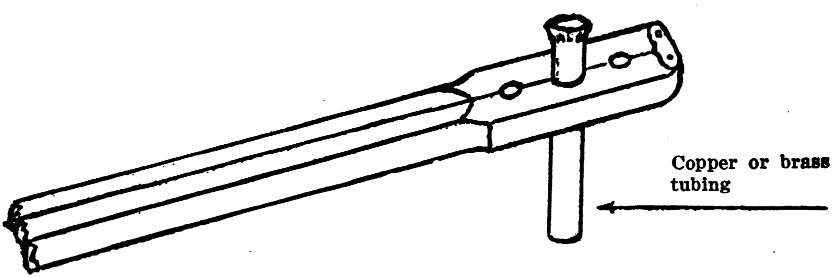


FIGURE 28.—Flanging tubing.

CUTTING SHEET ALUMINUM

The simple and best way to cut sheet aluminum is to break it. All the tools necessary is some kind of sharp tool and two pieces of angle iron.

Lay out the aluminum accurately, then place the piece to be cut between the two pieces of angle iron, as shown in figure 29, with the line marked just showing above the angle iron.

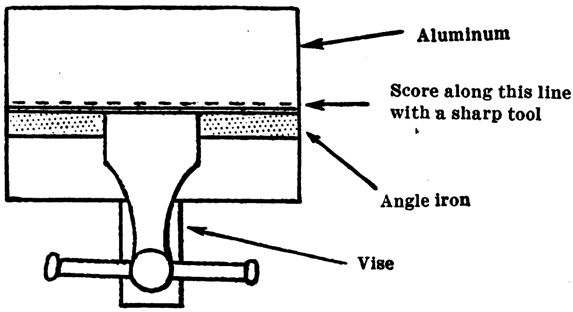


FIGURE 29.

Clamp this firmly in a vice. Then take a sharp tool—a wood chisel will do—and with a firm pressure run along the line, making a deep cut in the aluminum. Repeat this three or four times. Then, leaving the aluminum in the same position, do the same thing on the other side. This will score the surface of the metal and allow a clean break to result.

After making several of these deep cuts on each side, grasp the top of the sheet in both hands and work it slowly back and forth being careful not to bend it too far in either direction. If you do bend it too far in either direction the aluminum will bend and will not be flat. After bending back and forth until the aluminum breaks take a file and touch up the edges. If care is used in marking off the sheet, it will be the exact size because the aluminum cannot break in any other place except where it is cut.

CUTTING ROUND HOLES IN ALUMINUM

Lay out the center of the hole to be cut with a centerpunch, and drill a very small hole in the exact center. With this as a center adjust a pair of heavy carpenter's or machinist's dividers to the radius of the hole desired and scribe a circle. Make cuts and then turn the panel over and make several cuts on the reverse side. Open a vise just a trifle larger than the diameter of the scribed circle, lay the aluminum over the opening of the vise and strike the inside of the circle several blows with the ball end of a ball-pean hammer, being careful not to bend the panel. Turn over and repeat. The same results can be obtained by laying the panel over a soft wood block and strike on alternate sides with the ball end of a ball-pean hammer. The aluminum will break along the scribed circle and a smooth even hole will result.

SMALL BEARINGS REMOVED QUICKLY WITH IMPROVISED PULLER

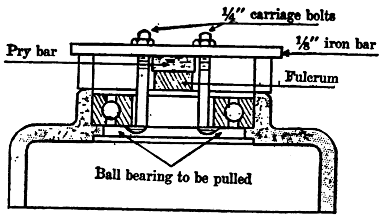


FIGURE 30.

Removing generator and other small bearings is made easy with this improvised puller which is assembled from a short piece of flat iron and a couple of carriage bolts. Let the bolt heads slip over the rear side of the race, then slip the bar over the threaded ends. A pry bar under the puller bar will pull the bearing.

SPARK TEST FOR HARDNESS OF METAL

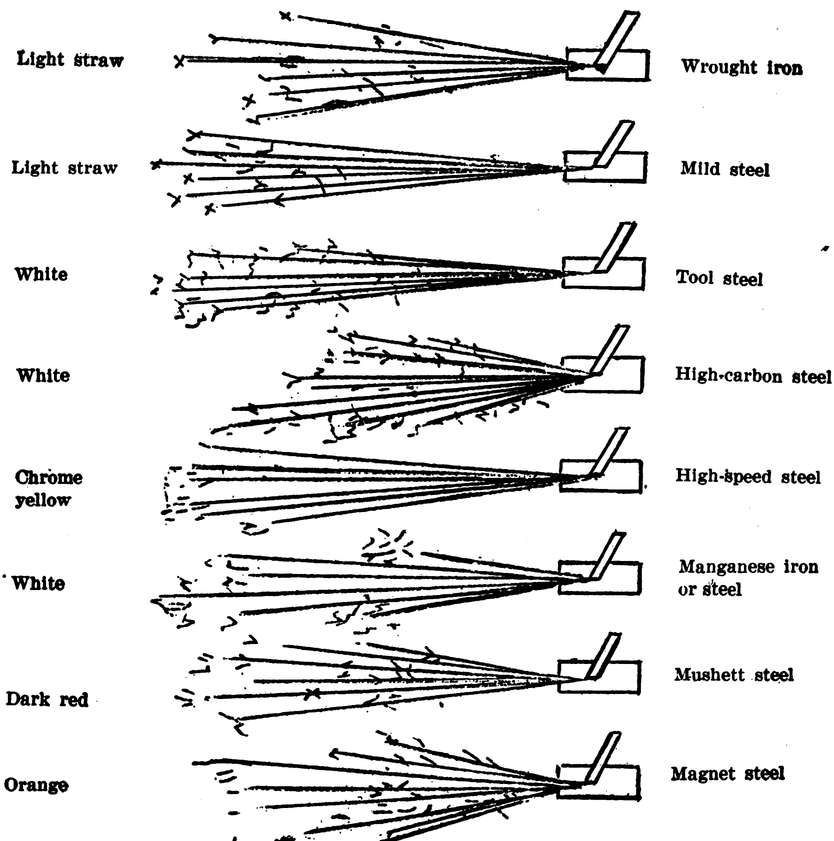


FIGURE 31.

QUESTIONS

1. What is annealing?
2. How would you anneal steel?
3. How would you anneal brass?
4. How would you anneal copper?
5. Explain two simple ways of bending tubing.
6. How is an outside mandrel put on a piece of tubing?
7. Why is it necessary to anneal tubing before bending?
8. Explain one method of flanging tubing.
9. Explain in detail a simple way to cut sheet aluminum.
10. Describe one method of cutting holes in aluminum.
11. How would you pull a small bearing?
12. How could you tell whether or not a drill was made of carbon steel or high-speed steel?

CHAPTER 7. WIRE SPLICING—CABLES

WIRE SPLICING

The requirements of a good splice are:

1. That it be both mechanically and electrically secure without solder.
2. That it be soldered well and neatly to prevent corrosion.
3. That it be well insulated with insulating rubber or friction tape or both.

The tools necessary are a pair of pliers and a sharp knife.

The first thing to do is to learn how to safely remove insulation from the wire. This is called "stripping" the wire. Wire used for lighting and power purposes is made with rubber covering which is protected on the outside with a cotton braid. The wire itself is made of copper and is tinned to prevent corrosion. Use the sharp edge of the knife for cutting, the back of the blade for scraping. By using the back of the blade for scraping you save the cutting edge from dulling. Never cut the insulation away as shown in figure 32, as in doing so you are liable to nick the wire.

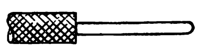


FIGURE 32.

FIGURE 33.

A wire can easily be broken if it is nicked and the circular cross section area of the wire is reduced by the nick, thereby increasing its resistance. The correct way to cut insulation from wire is to whittle the insulation off as you would sharpen a lead pencil until the rubber and braid have been removed, then with the back of the blade scrape off all the remaining rubber until the metal shines. After about 4 inches of the wire has been stripped and scraped clean and shiny, it is ready for splicing. Do not scrape off the tinning. Figure 33 is the way the wire should look when ready for splicing.

"T" Splice.

Strip about 4 inches of insulation off the end of the wire you are about to connect, and strip about 1½ inches of insulation off the running wire. Hold the wires firmly and make one turn backward on the main wire, then bring the end of the connecting wire back of where it started and twist onto the running wire for about six turns, finishing the splice. This splice is shown in figure 34 (b). An improper splice is shown in figure 34 (a).

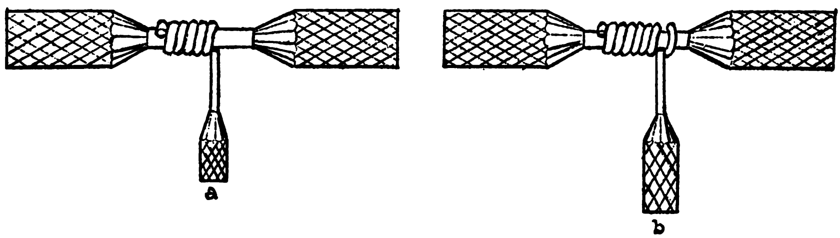


FIGURE 34.

Fixture Splice.

The fixture splice is largely used in wiring fixtures or in places where it is necessary to connect together wires of different sizes.

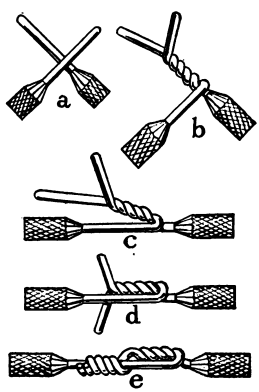


FIGURE 35.

First, strip the insulation off the two wires a distance of 5 inches and then scrape the wire clean and shiny. Hold the wires firmly as shown in figure 35 (a). Now twist the wires together with your pliers, making three complete turns, as shown in figure 35 (b). Be sure both wires twist together. If one wire only twists, and the other remains straight, the joint will not hold well and it will be mechanically as

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well as electrically loose. Straighten out the two ends as in figure 35 (c), and then bend the twisted portion close to the long wire, as shown in figure 35 (d). Wrap the two ends in the same direction around the long wire and the splice is completed and ready for soldering, as in figure 35 (e).

Western Union Splice.

The Western Union splice is the most common splice used in connecting wires. Strip off about 5 inches of the insulation and scrape the two wires clean and shiny. Hold them firmly in position as shown in figure 36 (a). Make five or six turns with one wire, as shown in figure 36 (b), then make the same number of turns in the other direction with the other wire. Cut the ends of the wires off short and be sure that the ends do not stick out, because the sharp points will cut through the insulating tape. Have turns tight and close together. There should be no movement between the two wires when the splice is finished. The finished splice is shown in figure 36 (c).

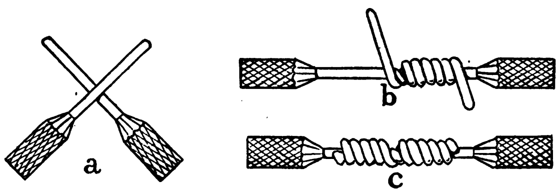

FIGURE 36.

In figure 37, a Western Union splice is shown as it should be used in a twin conductor. The one thing to note is that the splices are placed so that they cannot come in contact with each other.

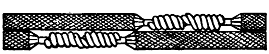

FIGURE 37.

Terminal Lugs.

Securing terminal lugs to the ends of wires is also an important undertaking. The wires should first be stripped of insulation sufficiently to allow it to be inserted fully in the lug. The wire should first be tinned, using a good flux. Heat the lug by blow torch and melt solder in the lug until about two-thirds full. Insert the wire and let cool. Care must be exercised to prevent the smallest movement of the work when the solder is passing from the fluid state to hardness.

FIGURE 38.

Eye Splice.

Where any eye splice is to be served, before starting to turn the eye, carefully paint, worm, parcel and serve that part which is to lie in the thimble, allowing plenty of end beyond the serving for hauling through tucks of strands. If the eye is not to be served, put a whipping on at a reasonable distance from the end, whipping each strand and unlay the strands beyond the whipping.

Break the eye around the thimble and seize it in place. Put the wire on a stretch at about waist height. With the strands lying about parallel to the part of the wire through which they are to be tucked, stand with the thimble on your left side, and face in the direction in which the tuck is to be made. Take the left hand strand and, using a pricker and marlin spike to open the lay, tuck it under two strands at the left fairly close to the throat of the thimble. Withdraw the spike and haul the strand down snug. Then take the next strand to the right of the first one tucked and tuck it in the same point, both under one strand. Pull it down snug.

Now take the next strand and tuck it in the next lay, under one strand and coming out where the first two strands were tucked in. Work around to the right, tucking each strand to the left, under one strand. Pull all strands snug.

Starting with the first strand tucked, pass each strand over one strand and under one, completing two full tucks. Haul down snug. Then halve each strand and tuck the reduced part in the same manner as the second tuck was taken. Quarter and tuck again. The result is a tapered eye splice.

Gun Factory Splice.

Seize wire with marline about 2 feet from end to prevent unraveling while splicing. Then whip each end of the six strands. Now wire is ready for splicing. After the size of eye required has been determined, start splicing as follows: Tuck first strand under three, second under two, third strand under one. The other three strands are tucked under one and over one. The remaining tucks are under one and over one.

CABLES

Rubber Insulated Cables, Fixed Installations.

Rubber insulated cables for fixed installations shall be furnished in the following types, as required:

Type SICP—Single, instrument cable, plain.
Type SLPP-4—Single, lighting and power, plain.
Type SLPA-4—Single, lighting and power, armored.
Aype SRLL-4—Single, radio use, low-tension, leaded.
Type SRHLA-4—Single, radio use, high-tension, leaded and armored.

Type DLPP-4—Duplex, lighting and power, plain.
Type DLPA-4—Duplex, lighting and power, armored.
Type DLB-4—Duplex, lighting, braided.
Type DRHLA-4—Duplex, radio use, high-tension, leaded and armored.
Type TRLL-4—Twin, radio use, low-tension, leaded.
Type TLPP-4—Triplex, lighting and power, plain.
Type TLPA-4—Triplex, lighting and power, armored.
Type TRHLA-4—Triplex, radio use, high tension, leaded and armored.
Type FLB-4—Four conductor, lighting, braided.
Type FLP-4—Four conductor, lighting, plain.
Type FLA-4—Four conductor, lighting, armored.
Type GICP—General interior communication, plain.
Type GICA—General interior communication, armored.
Type BW-3—Bell wire.
Type BC—Bell cord.
Type VLS—Voltmeter leads, submarines.

Rubber Insulated Cables and Cords—Very Flexible Uses.

Rubber insulated cables and cords in the very flexible class and/or intended for use as portable leads shall be furnished in the following types, as required:

Type SCP—Single conductor, portable.
Type DCP—Double conductor, portable.
Type TCP—Triple conductor, portable.
Type MCP—Multiple conductor, portable.
Type GICF—General interior communication, flexible.

Varnished Cambric Insulated Cables.

Varnished cambric insulated cables for fixed installations shall be furnished in the following types, as required:

Type SLPP—9 (and larger)—Single, lighting and power, plain.
Type SLPA—9 (and larger)—Single, lighting and power, armored.
Type DLPP—9 (and larger)—Duplex, lighting and power, plain.
Type DLPA—9 (and larger)—Duplex, lighting and power, armored.
Type TLPP—9 (and larger)—Triplex, lighting and power, plain.
Type TIPA—9 (and larger)—Triplex, lighting and power, armored.

Flameproof Cables.

Flameproof cables for fixed installations shall be furnished in the following types, as required:

Type SFPP—Single, flameproof, plain.
Type SFPA—Single, flameproof, armored.
Type DFPP—Duplex, flameproof, plain.
Type DFPA—Duplex, flameproof, armored.
Type TFPP—Triplex, flameproof, plain.
Type TFPA—Triplex, flameproof, armored.
Type FFPP—Four-conductor, flameproof, plain.
Type FFPA—Four-conductor, flameproof, armored.
Type MFPP—Multiconductor, flameproof, plain.
Type MFPA—Multiconductor, flameproof, armored.
Type SFPS—Single, flameproof, switchboard and panel wiring.

Silk, Cotton, and Enamel Insulated Cables, Cord, and Wires.

Cables, cords and wires insulated with silk, cotton, and enamel shall be furnished in the following types, as required:

Type TSW—Telephone switchboard wire.
Type TPTP—Twisted pair, telephone, plain.
Type TPTA—Twisted pair, telephone, armored.

Cable Sizes.

The several sizes of cable within each of the foregoing classes and types shall be as indicated by a numeral after the type letter designation.

Color Code.

Except where otherwise specifically required or approved, the following color code shall apply to all cables having from 1 to 44 (inclusive) individually insulated conductors within a common protective sheath. For example, all single-conductor cables would be 1 black, all two-conductor cables would consist of 1 black and 2 white, all three-conductor cables would consist of 1 black, 2 white, and 3 red, etc., up to a 44-conductor cable; where all the color combinations listed would be included. In the case of cables having more than 1 layer of conductors, the numbering shown above shall be from the innermost to the outermost i. e., the No. 1 conductor shall be the center conductor (or one of the center conductors where two or more are used as a center) of the concentric lay.

Conductor No.	Base color	Tracer color	Tracer color
1	Black		
2	White		
3	Red		
4	Green		
5	Orange		
6	Blue		
7	White	Black	
8	Red	do	
9	Green	do	
10	Orange	do	
11	Blue	do	
12	Black	White	
13	Red	do	
14	Green	do	
15	Blue	do	
16	Black	Red	
17	White	do	
18	Orange	do	
19	Blue	do	
20	Red	Green	
21	Orange	do	
22	Black	White	Red.
23	White	Black	Do.
24	Red	do	White.
25	Green	do	Do.

Conductor No.	Base color	Tracer color	Tracer color
26	Orange	Black	White.
27	Blue	do	Do.
28	Black	Red	Green.
29	White	do	Do.
30	Red	Black	Do.
31	Green	do	Orange.
32	Orange	do	Green.
33	Blue	White	Orange.
34	Black	do	Do.
35	White	Red	Do.
36	Orange	White	Blue.
37	White	Red	Do.
38	Brown		
39	do	Black	
40	do	White	
41	do	Red	
42	do	Green	
43	do	Orange	
44	do	Blue	

QUESTIONS

1. What are the requirements of a good splice?
2. How should a wire look when ready for splicing?
3. What side of a knife would you use to scrape wire with?
4. How would you make a tap splice?
5. Describe the method for making a fixture splice.
6. How would you make a western union splice?
7. How would you secure a terminal lug to the end of a wire?
8. Describe the method used in making an eye splice in wire rope.
9. Tell how you would make a gun factory splice in wire rope.
10. What is the meaning of SLPP–9?
11. How is the size of cable designated?
12. Why are cables color coded?

CHAPTER 8. PRECAUTIONS TO BE OBSERVED WHEN USING GASOLINE

Characteristics of Gasoline and Gasoline Vapor.

Gasoline is a highly volatile liquid which will give off an inflammable vapor if left exposed to the air. Air at ordinary atmospheric temperatures will absorb from 5 to 28 percent of gasoline vapor, the amount depending on the quality and grade of the gasoline, the lighter and better grades causing the higher percentages. Gasoline vapor is about three times as heavy as air, and in a room containing gasoline vapor the highest percentage is found near the floor. However, the mixture will gradually diffuse throughout the whole room.

Formation of Explosive Mixture.

The low limit of explosibility of gasoline vapor and air is about 1.4 percent. One quart of gasoline left exposed in a closed space will render explosive upon complete evaporation under ideal conditions, 525 cubic feet of air, or a space of 10 feet square by 5¼ feet high. One cubic inch of gasoline will do the same thing for a space 9 cubic feet, or a space 3 by 3 by 1 foot. These figures will give an idea of the minuteness of the amount of gasoline needed to produce an explosive mixture.

Explosion of Gasoline Vapor.

The mixture formed by gasoline vapor and air is highly explosive in character and needs but a slight spark to set it off, a violent explosion and a very hot roaring fire resulting. A dangerous feature of gasoline vapor is that it may travel a considerable distance from the gasoline and there be ignited, the flash traveling back to the source of supply and causing an explosion or fire some distance from the location of the spark. This is especially important in connection with safety regulations as regards smoking in the vicinity.

Accumulation of Vapor Prevented by Ventilation.

In gasoline engine installations, and where gasoline is stored, it is difficult to prevent slight leaks in the gasoline system. This will cause gasoline vapor to be present more or less continuously, especially in the lower spaces, such as bilges, under floor plates, etc. The danger of the spark necessary for an explosion is always existent and cannot be wholly eradicated. Therefore, it is of the utmost importance to prevent the accumulation of the vapor in sufficient quantity to form an explosive mixture. This can be done by proper ventilation.

Instruction of Personnel.

Owing to the widespread use of gasoline, and the varying circumstances under which it is handled, no precautions that can be devised should be deemed of greater importance than the thorough instruction of all personnel in regard to its dangers and the methods of prevention of gasoline fires.

Bilges in Motor Boats To Be Kept Dry.

Practically all the fires in gasoline power-driven boats are initiated as a result of, or continued by, the accumulation of gasoline or its vapors and by-products in the bilges.

Use in Confined Spaces Prohibited.

Gasoline and other volatile liquids which give off inflammable, asphyxiating, or otherwise dangerous fumes, shall not be used in confined or enclosed spaces, or in such manner as to be dangerous to personnel or material.

INSPECTIONS

The following inspections apply before starting an engine that has not been in use since the day before, has been under overhaul, or has been idle for an appreciable period. These inspections should also be made daily, in the case of a power boat, secured or in the cradle.

Inspect Engine.

To see that all electrical connections are in place and secured.

Gasoline Piping and Tank Fittings.

Inspect for leaks and immediately remedy any found. See that the filling plug is in place.

Wire Gauze Screens.

Inspect to see if intact and clean. Those over carburetor and breather pipe connections must be securely clamped to prevent blowing loose in case of a backfire or a crank-case explosion. All wire gauze screens must be of the multiple-screen type and approved by the Bureau of Ships.

Carburetor Drip Pan.

Inspect and empty. The drip pan should be inspected, emptied and washed when the engine is stopped, at intervals when the boat is running during the day, and before hoisting to its cradle. *Drip pans are safe only when kept empty.*

Bilges and Sumps.

Inspect to see if dry and free from gasoline vapor and oil.

Ventilation.

Is of prime importance at all times and all spaces subject to accumulation of gasoline vapor shall be inspected and thoroughly ventilated. The time when gasoline fires are most liable to occur is when starting an engine. Before starting, every precaution should be taken to insure that the bilges are not only opened up to ventilation, but that gasoline, or gasoline vapor, present in bilges and sumps is removed. Where special exhauster fan is fitted, it should be run at least 5 minutes before starting the engine, intermittently for an aggregate of at least 1 hour daily in addition to this, and at any time when the presence of gasoline vapor is suspected. Bilge pumps should be run for at least 1 hour after the bilges dry and pump is pumping air, in order to remove the vapor, and in addition, it should be run at such other times as the presence of gasoline vapor is suspected or liable to accumulate. After each fueling, and before starting, open the hood of the engine for the purpose of ventilation.

FIRE-FIGHTING EQUIPMENT

(*a*) Each boat crew shall be instructed in care and use of fire-fighting equipment provided for and installed in every power boat. Fire extinguishing equipment is under the cognizance of the Bureau of Construction and Repair.

(*b*) Portable fire extinguishers other than CO_2 type shall be inspected frequently to insure that they are in sufficient operating condition ready for instant use. In cases where a CO_2 system is provided, the cylinder should be disconnected and weighed at intervals of 3 months, and a record thereof should be kept on the cylinder record card provided by the manufacturer. The card is to be kept in the "remainder file" in the First Lieutenant's office, or, where no such office exists, in the ship's writer's office. When upon being weighed a CO_2 cylinder has been found to have lost 10 percent of its rated capacity, it must be refilled.

(c) Fire cannot exist in carbon dioxide due to lack of oxygen, the essential element of combustion. If diffused in air in sufficient quantities, it will extinguish a fire. A fire in such compartments as fireroom, motor room, oil-pumping room, oil-control rooms, cargo spaces, storerooms, and in engine rooms of motor boats is best extinguished by diluting the atmosphere in the entire compartment by the introduction of carbon dioxide.

(*d*) To fight boat fires, carbon dioxide portable hand and built-in types of extinguishers will be installed and carried in the boats.

(*e*) These extinguishers shall be so located that at least half of them can be immediately reached regardless of the location of the fire.

(*f*) When a carbon tetrachloride extinguisher is used on a fire in confined spaces, the fumes of decomposition have a dangerous suffocating effect which must be guarded against.

(*g*) In boats equipped with a permanent CO_2 fire extinguishing apparatus, it is very important that the CO_2 flasks always have sufficient gas in them to function properly.

(*h*) The chemicals in the foam type extinguisher begin congealing at temperatures below 40° F. In cold weather suitable precautions should be taken to protect this type of extinguisher. All types of fire extinguishers shall be tested as prescribed in the Construction and Repair Manual.

GASOLINE FIRE EXTINGUISHING

In case of gasoline fire, the danger may be minimized by using one or more of the following methods of extinguishing the fire:

(*a*) Use carbon dioxide extinguishers (carbon tetrachloride or foam types of fire extinguishers, if still on board). NOTE.—*The solution in foam-type extinguishers is injurious to electrical equipment and the use of it involves risk of causing electrical short circuits and leakage.*

(*b*) Smother the fire if possible, by means of wet blankets, mattresses, or similar material. If the fire is in a closed compartment seal it to prevent access of air. If possible throw into the compartment, one, or several, *opened* carbon dioxide portable extinguishers. Each 15-pound capacity portable extinguisher is capable of rendering an atmosphere of 250 cubic feet sufficiently inert to extinguish a fire.

(*c*) Water is effective in extinguishing gasoline fires only under the following conditions:

(1) To sweep the flames on the water away from a ship or dock.
(2) To completely flood a compartment on fire.
(3) When it can be supplied with sufficient pressure and volume to have a smothering effect and distributed over the entire area by spray, otherwise the burning gasoline floating on the surface of the water may spread the fire to other substances.

Smoking.

No smoking or naked lights shall be permitted in power boats, nor where gasoline or other volatile liquids or gasses are present.

Sparks.

May be formed by striking a nut with a wrench, by arcing of the brushes of a motor, by grounds or shorts in electrical circuits, by arcing of any electrical apparatus, by opening any switches carrying current, by the turning off of an ordinary electric switch, by induced electric charges formed by rubbing of two surfaces together, by the motion of a rapidly moving power belt, by nails in shoes hitting or rubbing metal or stones. It is possible for an induced charge of electricity of considerable magnitude to be formed by friction of gasoline in a metal funnel used for filling gasoline containers and insulated from the container. The funnel may subsequently make a spark when touched to the metal container. The necessary spark can be produced in so many ways that reliance cannot be placed upon safety measures designed to control this feature alone, and the most careful precaution is necessary against the accumulation of gasoline vapor. To avoid danger of gasoline igniting from a static spark, the filling hose nozzle is provided with a grounding wire which should be grounded to some part of the tank which is to be fueled, prior to the opening of the filling flap. This connection will equalize electrical potential. The ground should be maintained throughout the operation of fueling and until the hose has been withdrawn and the filling flap closed. The use of a funnel increases the danger from sparks. It is, therefore, preferable to insert the nozzle of the grounded hose directly into the filling opening on the tank.

QUESTIONS

1. At ordinary atmospheric temperatures, what amount of gasoline vapor will the surrounding air absorb?
2. Is gasoline vapor heavier or lighter than air and in what proportion?
3. In a room containing gasoline vapor the highest percentage is found where?
4. What is the low limit of explosibility of gasoline vapor and air?
5. Give an example conveying how highly explosive gasoline vapor is.
6. What is necessary to explode an atmosphere containing an explosive mixture of gasoline vapor and air? What is the result?
7. Why is it that NO SMOKING signs are posted at considerable distance from where gasoline tanks and dispensers are located?
8. In what manner is the danger of gasoline vapor and air explosions minimized?
9. Can the ever present danger of sparks within the vicinity of gasoline be eliminated? Why?
10. What is the unit of measure of gasoline?
11. The leaflet form on specifications of gasoline issued by what Naval Bureau?
12. What causes the most fires in gasoline power boats?
13. Why is the use of gasoline and other volatile vapors prohibited in confined or enclosed spaces?
14. When is a gasoline fire in a power boat most apt to occur?
15. Explain the sequence of operations in properly ventilating the bilges and sumps of a power boat?
16. Fire fighting equipment comes under the cognizance of which Bureau?
17. Explain in detail the inspection of the CO_2 types of fire extinguisher?
18. When must a CO_2 fire extinguisher be refilled?
19. Fire cannot exist in carbon dioxide because of what?
20. What is the danger of employing a carbon tetrachloride type extinguisher to put out a fire?

21. What precautions must be observed in care of foam types of extinguishers during low temperature wheather?
22. In accordance with instructions of what manual, are all types of fire extinguishers tested?
23. In what three ways only, is water effective as a partial or thorough method of extinguishing gasoline fires?
24. Name several ways that sparks may be unintentionally produced, which are sufficient to ignite an explosive mixture of gasoline vapor and air.

CHAPTER 9. RADIO MANUFACTURERS' ASSOCIATION STANDARDS

RESISTORS AND CAPACITORS

Small resistors and capacitors are often marked with dots or bands of color to indicate their values as an aid to both repair man and manufacturer. Components too small to have the actual values printed upon them are easily color-coded, and have the further advantage that these bands of color can be seen at all times without the probable necessity of turning the units over or otherwise searching for the printed value. The standards Committee of RMA (Radio Manufacturers' Association) has standardized a group of colors with numerical equivalents as follows:

0=Black	5=Green
1=Brown	6=Blue
2=Red	7=Violet
3=Orange	8=Gray
4=Yellow	9=White

This color code is standard for all resistors and capacitors, although there are several systems employed in its use. In general, however, several dots or bands of color are used to indicate the *significant figures* of the value, and a final color to indicate where to place the decimal point. This "decimal multiplier" color indicates the *number of zeros* to be added to the significant figures or, which amounts to the same thing, the power of 10 that the significant figures must be multiplied by in order to properly place the decimal point. Thus, three RED dots indicate the number 2200, the first two dots contributing the 22 part, and the last dot, being the decimal multiplier, indicating that two ZEROS are to be added (or multiply by 10 to the second power) to complete the value. Likewise, the combination red-orange-green-black indicates the number 235. In this case the black decimal multiplier (black=0) means "add NO zeros," or multiply by 1 (10 to the zero power=1).

The original colors have since been supplemented by gold and silver, and the significance of each color has been extended to include tolerance values, capacitor voltage ratings, and capacitor temperature coefficients, as shown in table II. These additional features of the *extended* color code may never be employed, however, except in the single case of resistors having *five* bands, or capacitors having *six* dots or bands to indicate the value to three significant figures in a specific manner which will be shown. For all other applications, gold and silver are *never* used for any purpose other than to indicate tolerance and, conversely, the tolerance must *never* be indicated by any color other than gold or silver. In the several accompanying illustrations, the encircled numbers are employed to indicate the relative order and positions of the significant figure colors, that is, ①=first significant figure, ②=second, etc. The location of the decimal multiplier color is indicated by ⓧ, the tolerance color by (%), and the voltage rating of capacitors by Ⓥ.

TABLE II.—*RMA Standard* **Extended** *Color Code for Resistors and Capacitors*

Color	Significant figure	X Decimal multiplier	% Tolerance ± %	V Voltage rating, volts	TC Temperature coefficient
Black	0	1	20	----------	Zero
Brown	1	10	1	100	−30
Red	2	10^2	2	200	−80
Orange	3	10^3	3	300	−150
Yellow	4	10^4	4	400	−220
Green	5	10^5	5	500	−330
Blue	6	10^6	6	600	−470
Violet	7	10^7	7	700	−750
Gray	8	18^8	8	800	----------
White	9	10^9	9	900	Not specified
Gold	----------	10^{-1}	5	1,000	----------
Silver	----------	10^{-2}	10	2,000	----------
No color	----------	----------	20	500	----------

Resistors.

There are in use two distinct systems for color-coding the values of small fixed composition resistors and, although the first, or "old system," is now obsolete for all resistors except those having "radial" connecting leads (see fig. 39 (A)), many resistors having this type of marking are still in use. The original system consists of painting the entire resistor with a solid *body color* to indicate the first significant figure of the resistance value, which is always expressed in ohms. At one end of the unit, and painted right over the body color, is the *end color* which indicates the second figure. Near the middle of the unit, also painted on top of the body color, is the *dot color* which serves as the decimal multiplier, and consists of a large dot or a band of color. Resistors employing this system of arranging the colors may sometimes be found with a gold or silver "tolerance band" which may appear at either the same or at the opposite end from the "end" color. Inasmuch as there are no blank spaces between adjacent colors, it is obviously unnecessary to paint a red dot or end on a resistor already having a red body color. A resistor that is entirely red without any other markings, then, would have a resistance of 2200 $\Omega \pm 20\%$, because its "body," "end," and "dot" colors are all red. The following illustrations show typical examples of the "old" color code.

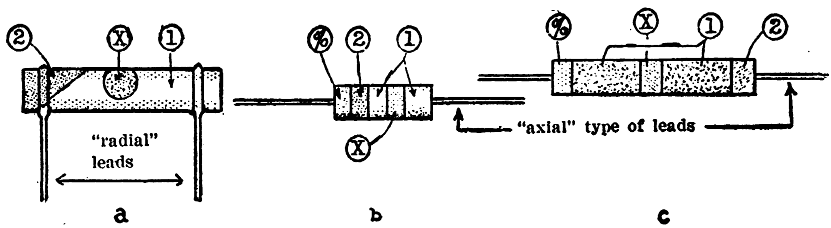

FIGURE 39.

The new system is now standard for all fixed composition resistors except those few which have their connecting wires attached radially instead of axially. It is easier to read because the bands always extend entirely around the unit, and the colors are taken in a more logical sequence. The system also permits values to be expressed to more than two significant figures, it being standard to indicate all values to three significant figures unless the tolerance is greater than $\pm 10\%$, when two figures are then considered satisfactory. Markings consist of several encircling bands of color having approximately the same width, *with spaces between* them, and which are simply read in the order that they appear on the resistor, always commencing with the band which is painted at the very *end* of the resistor. Three bands are used to indicate the value to two significant figures, and the tolerance *may* be indicated, when desired, by an additional band provided it is of either gold or silver.

To indicate the value to *three* figures the new extended code is used, such units being readily identified by the presence of *five bands* of color. The decimal multiplier and tolerance colors may be of any color listed in Table II, but it must be remembered that the resistor must have all *five bands* before the extended code may be employed. Note that the *background* color of the resistor itself plays no part in the color code, and is not to be confused with the "body color" of the older system. The actual background color of *insulated* resistors (regardless of whether they are of the carbon, composition, or wire-wound type) is usually a light brown or tan, this being the natural color of the bakelite insulating material. Following examples illustrate the new method of employing the color code:

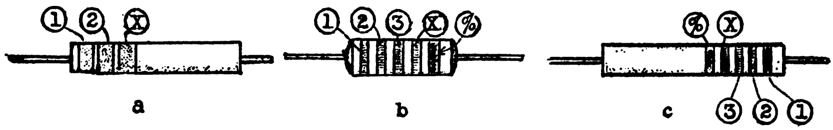

FIGURE 40.

Capacitors.

Capacity is indicated by colored dots or bands according to the same general plan used in the new color code for resistors. It is standard to designate values in micro-micro-farads in all cases unless the capacity exceeds 10,000$\mu\mu$f, in which case the capacity is to be designated in micro-farads (10,000$\mu\mu$f=0.01μf). Capacitors with mica dielectric are not to be manufactured in voltage ratings less than 500 volts. As was the case regarding resistance values, capacity is indicated to three significant figures unless the tolerance is greater than ±10%. Small molded mica capacitors of the so-called "postage stamp" variety, which have a voltage rating of 500 volts, employ three colored dots in a horizontal row which indicate two significant figures and a decimal multiplier. Dots are taken in the order in which they appear from left to right when the capacitor is viewed right side up. The presence of a trade mark or other printed matter readily indicates which is the upper edge, and in the absence of any printing there is always an arrow, arrow heads on one or more of the dots, or some other obvious indication of the direction in which the dots are to be read. These small condensers very seldom have a tolerance dot. Following are typical examples:

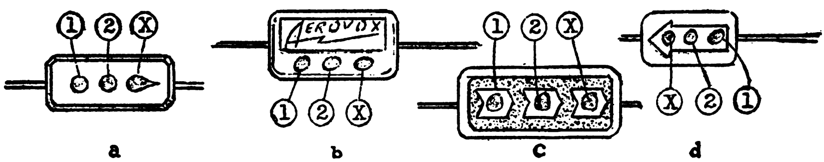

FIGURE 41.

Flat capacitors of more or less rectangular cross-section, most especially molded mica capacitors, and which have voltage ratings greater than 500 volts, are marked with *two* horizontal rows of dots. The upper row, reading from left to right, indicates the significant figures of the value. The lower row, reading from *right to left*, indicates first the decimal multiplier, then the tolerance, and last the voltage rating. Note that *either* row of dots may be correctly read from left to right provided the capacitor is turned around in such a manner as to place that particular row in the upper position. The presence of a trade mark or other printing will indicate which is the upper edge of the capacitor, although in the absence of all printing it may sometimes be necessary to decipher both possible interpretations and decide which one seems the most logical. In such cases it will usually be found that one of the interpretations indicates an impossible value. All values of decimal multiplier and tolerance colors in the *extended* code are applicable in this case where all *six colors* are invariably employed. Following examples illustrate the standard system employed to mark capacitors of this type:

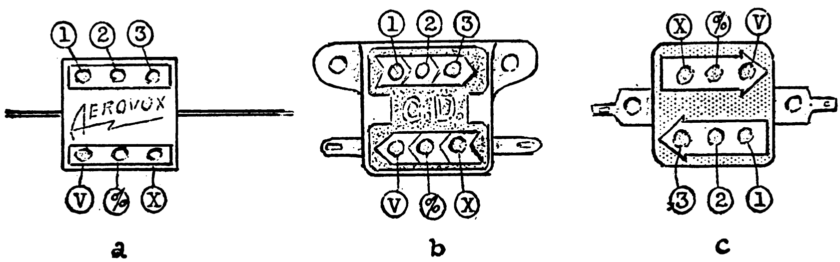

FIGURE 42.

There are still in use many mica capacitors which were color coded using systems differing from those just described. Some were in general use before standardization of the new systems by RMA, and others have been peculiar only to the manufacturer who introduced them. The special features of the extended code are *not* applicable in any of these special cases.

Capacitors like those illustrated in figure 42 in some instances have been marked with values having only two significant figures by simply utilizing only the upper row of dots and leaving the lower row blank. Sometimes a gold or silver tolerance color appears in one (*any* one) of the unused blanks in the lower row.

In a very widely used nonstandard system for expressing values to *three* significant figures, exactly the same procedure is followed for the first two dots as in the small capacitors just described, but the space normally occupied by the third dot is left uncolored, and the remainder of the code is placed elsewhere. The reason for leaving the third dot blank is that this dot normally indicates the number of zeros to be added to the significant figures, so that the omission of color from the third dot might be interpreted to indicate "Read third significant figure *before* adding zeros." The remainder of the code, as mentioned above, is located elsewhere, either on the lower edge of the front of the capacitor or across the back. In either case the dots are read from left to right unless otherwise indicated, the first dot indicating the *third* significant figure in the capacity value, and the last dot indicating the number of zeros that follow these three figures. One very important detail to notice is that the second group never employs more than two colored dots, and these always occupy the first and third positions with the middle one remaining blank. But the first group *always* has the first two dots colored, and may have the third either colored or blank, depending on whether the value contains two or three significant figures. Sometimes this fact will be the only indication as to the way to hold the capacitor while reading the colors.

Any of the unused spaces may contain a gold or silver dot to indicate the tolerance. Following are examples of this now obsolete system of color coding capacitors for values to three significant figures:

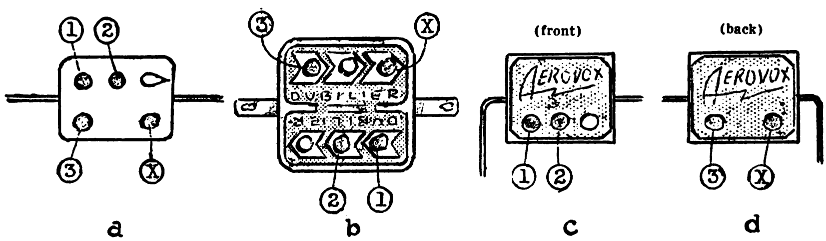

FIGURE 43.

Another system, introduced prior to the appearance of the new RMA code, is based on the conventional single horizontal row of three dots already described, and is used in the standard way to express values to two significant figures. A raised rectangular space is provided for the location of an additional dot to indicate the *third* significant figure when desired. (See fig. 44.) When the extra dot is not used, it is invariably painted black. There is also provided a space for a gold or silver dot to indicate the tolerance, when desired.

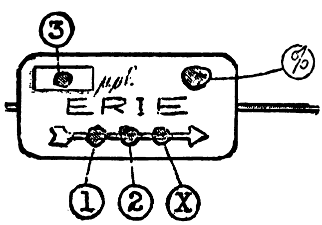

FIGURE 44.

Capacitors having a circular cross-section, especially the so-called "tubular" paper capacitors and those with mica or ceramic dielectric which are encased in small ceramic tubes, are marked with bands in a manner similar to that employed for resistors. The standard system consists of two groups of bands, one having bands much wider than the other. Both groups are arranged to be taken in the order starting from the *center* of the unit and reading outward toward the end of the unit. The group of wide bands indicates the significant figures of the value, and the narrow bands indicate respectively the decimal multiplier, the tolerance, and the voltage rating. All values of decimal multiplier and tolerance colors in the extended code are applicable in this case where all *six colors* are invariably employed. The following examples illustrate this standard system:

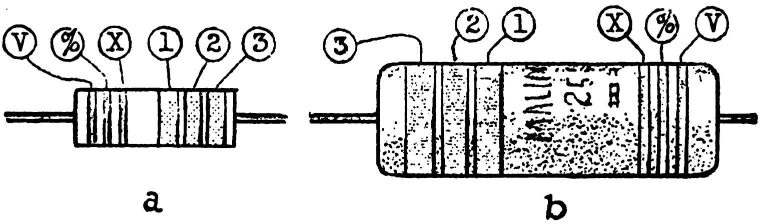

FIGURE 45.

The temperature coefficient of capacitors having deliberate and predetermined sensitivity to temperature changes is indicated by one of the regular colors of the color code, as shown in the last column of table II. A temperature coefficient of -30 is to be interpreted to mean: -30×10^{-6} $\mu\mu f/\mu\mu f/°C.$, or, in other words, each individual $\mu\mu f$ of capacity will undergo a change of -30×10^{-6} $\mu\mu f$ for each degree Centigrade change in temperature.

The *background* color of molded mica-dielectric capacitors is normally the dark brown color of the bakelite case. Yellow cases often indicate the use of a special low-loss mica-filled bakelite, and red cases indicate that the capacitor is of the *silver-mica* type, also encased in mica-filled bakelite.

The ASA *American War Standard* Codes.

New standards for radio materials and parts are being developed under the War Procedure of the *American Standards Association* (ASA) at the request of the War Production Board and with the co-operation of the War and Navy Departments, the Institute of Radio Engineers, the prime contractors, and the parts manufacturers concerned.

The new American War Standards for fixed mica-dielectric capacitors were approved on November 12, 1942. Capacitors are marked with either a "type designation" or are color coded, both methods of marking to be in accordance with the information contained in Table III. Note that any tolerance or particular group of *characteristics* may be indicated by means of either a color *or a letter.*

TABLE III.—*The ASA* **American War Standard** *code for fixed Mica-dielectric capacitors.*

Color	Significant figures	Decimal multiplier	Tolerance	Characteristics			
				Letter	Q	Temperature coefficient in parts/million/° C.	Maximum capacitance drift
Black	0	1		A	Not specified	Not specified	Not specified.
Brown	1	10		B	[See Table III-a].	Not specified	Not specified.
Red	2	100	2% [G]	C	do	−200 to +200	0.5%.
Orange	3	1000	2. 5% [H]	D	do	−100 to +100	0.2%.
Yellow	4			E	do	0 to +100	0.05%.
Green	5			F	do	0 to +50	0.025%.
Blue	6			G	do	0 to −50	0.025%.
Violet	7						
Gray	8						
White	9						
Gold		0. 1	5% [J]				
Silver		0. 01	10% [K]				
Black			20% [M]				

TABLE III–*a.—Approximate minimum values of Q for capacitors having characteristics other than A, measured at 1 megacyle.*

Capacitance in $\mu\mu F$	Minimum Q
5	140
10	230
20	340
50	550
100	770
200	1030
500	1370

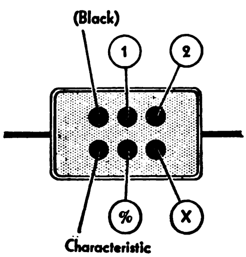

FIGURE 46

When color-coded, the capacitors appear identical to those marked in accordance with the standard RMA six-dot system, the only obvious difference being that the first dot is *always* painted Black to signify the use of the ASA code, and does *not* indicate the first significant figure of the capacitance value. Referring to Figure 46, a 360$\mu\mu$f capacitor with a 5% tolerance and having the C-type characteristics would be color-coded as follows: black—orange—blue—brown—gold—red (colors to be read from left-to-right across the top, and right-to-left across the bottom of the capacitor).

The type designation is a group of nine characters arranged in the following order: *Component* (indicated by two letters which, in this case, are always "CM", meaning "Capacitor, Mica-dielectric); *Case* (two figures to indicate the style and dimensions of the case); *Characteristic* (one "characteristic letter" from table III); *Capacitance* (three digits,—two for significant figures, and the third for the decimal multiplier); and finally the *Tolerance* (one letter from the Tolerance column of table III). For example, the capacitor just color-coded above would have the type designation CM 20 C 361 J which would be interpreted as a fixed mica-dielectric capacitor in a "type 20" case, and having characteristics as indicated in table III along the same line as that occupied by the color Red, or the characteristic letter C. The capacitance value is indicated by the numbers 361, which are interpreted in the same manner as would be the colors orange—blue—brown, that is, 36 followed by one *zero*, or 360$\mu\mu$f. The tolerance would be 5%, as indicated by the letter J in the tolerance column of table III.

Ceramic-Dielectric Capacitors.

The *American War Standard* (or ASA) code for fixed ceramic-dielectric capacitors is listed in table IV, and is employed in much the same manner as the RMA code for those resistors having axial connecting wires. Unlike the mica-dielectric capacitors previously described, these units are intentionally made in such a manner as to have predetermined sensitivity to variations in temperature. The temperature coefficient of capacitance is indicated by the color appearing on that end of the unit which provides the termination for the *inside* plate or electrode. This color covers the entire end of the capacitor, although the position in relation to the connecting wire may vary with different makes. The product of one manufacturer is shown in figure 47, and is typical of capacitors of this type. The next three dots adjacent to the temperature coefficient color indicate the value in $\mu\mu$f, and a final dot gives the tolerance. The tolerance must be expressed as a percent unless the capacitance value is less than 10$\mu\mu$f, as specified in table IV. Although the capacitor in figure 47 is shown with dots, it is standard to indicate the value and tolerance by means of either dots or bands, the choice being with the individual manufacturer. Capacitors with axial connecting wires are usually marked with bands instead of dots. Note the unconventional use of gray and white for decimal multiplier and tolerance colors in table IV.

TABLE IV.—*The ASA Code for Capacitors Having Ceramic Dielectric.*

Color	Significant Figures	Multiplier	Tolerance Values: Capacitance More than 10 MMF	Tolerance Values: Capacitance 10 MMF or Less	Temperature Coefficient in MMF/MMF/°C
Black	0	1	± 20%	±2.0 MMF	Zero ± .00003
Brown	1	10	± 1%	±0.1 MMF	−.00003 or − 30×10^{-6}
Red	2	100	± 2%	±0.2 MMF	−.00008 or − 80×10^{-6}
Orange	3	1,000	±2.5%	±0.25 MMF	−.00015 or − 150×10^{-6}
Yellow	4	.....	......	....	−.00022 or − 220×10^{-6}
Green	5	.....	± 5%	±0.5 MMF	−.00033 or − 330×10^{-6}
Blue	6	.....	......	....	−.00047 or − 470×10^{-6}
Violet	7	.....	......	....	−.00075 or − 750×10^{-6}
Gray	8	0.01	......	....	....
White	9	0.1	± 10%	±1.0 MMF	Not Specified

Temperature coefficient is expressed in MMF/MMF/°C. The standard tolerance of the coefficient is ± 15% or ± .00003 MMF/MMF/°C, whichever is the larger.

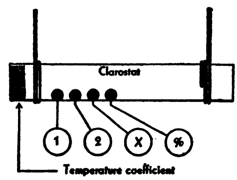

FIGURE 47.—Ceramic Capacitor.

PREFERRED NUMBER LIST

Preferred Numbers.

In 1936 the Engineering Department of "RMA" introduced and standardized the "Preferred Number Values of Fixed Composition Resistors." This system has so many advantages that it met with immediate approval and is now almost universally used. Basically, it is a logarithmic progression of significant figures such that each is separated from the next by approximately 10%, which enables the designer to obtain a standard unit that will more closely approach any value that he may require. The partial table gives only the significant figures, which may be multiplied by any desired power of 10 to obtain all values from 1 Ω to 10 megohms. The list is divided into three standard tolerance groups, and it can be seen that resistors having a tolerance of ±20% are available only in the values listed in that column. As these values have a separation of 40%, it can readily be seen that any conceivable value will fall within ±20% of one of the values in this column. The 10% group has a 20% interval between nominal values, and is the most often used, because in this group *any* resistance, no matter what its value, will fall within ±10% of one of the standard values listed in this column. This tolerance is usually sufficiently accurate for most radio circuits. Although great accuracy is sometimes necessary for special applications like cathode bias resistors, units of the 5% tolerance group should never be used unless this extreme accuracy is actually required.

TABLE V. *Preferred numbers*

±20%	±10%	±5%
10	10	10
		11
	12	12
		13
15	15	15
		16
	18	18
		20
22	22	22
		24
	27	27
		30
33	33	33
		36
	39	39
		43
47	47	47
		51
	56	56
		62
68	68	68
		75
	82	82
		91

NOTE:—It is standard to represent "ohms" by the symbol Ω, which is the capital Greek letter "Omega". The small, or lower-case Omega (ω) is not used for this purpose.

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