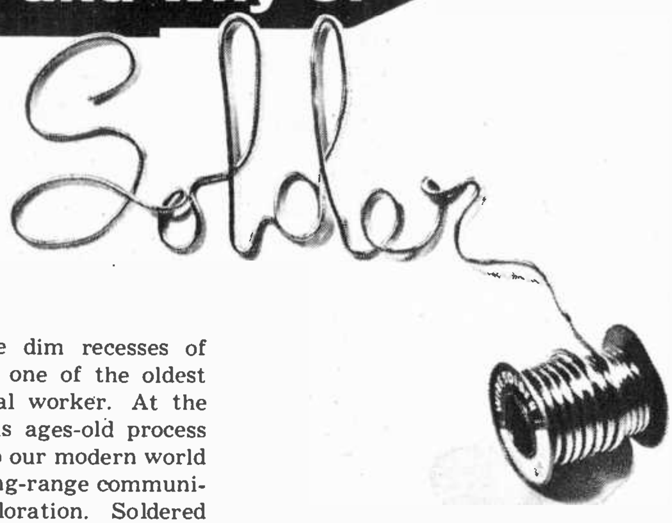
the how and why of Solder



By LOU GARNER

ORIGINATING in the dim recesses of history, soldering is one of the oldest arts known to the metal worker. At the same time, however, this ages-old process is of prime importance to our modern world of electronic controls, long-range communications, and space exploration. Soldered electrical connections are used in all types of electrical and electronic equipment, from the simplest pocket receivers to the most complex computers. They are found in the electronics gear used in vessels which explore the bottom of the sea as well as in satellites probing the depths of space.

Solder is an alloy, that is, a homogenous mixture of two or more elemental metals. The most popular solder is a mixture of lead and tin in varying proportions. Other elements may be present, such as cadmium, zinc, bismuth or antimony, but generally in very low percentages and, as often as not, as undesired impurities. A few special-purpose solders are made in which a third or fourth metal is added to the basic tin-lead alloy, but these solders are seldom encountered in day-to-day work.

Pure lead has a melting point of approximately 621°F; tin's melting point is 450°F. But the two metals blended together result in an alloy with a melting point lower than that of either metal alone. The exact melting point of the alloy depends on the ratio of tin to lead; generally, the more tin, the lower the melting point. See Fig. 1.

The lowest temperature at which solder will melt—361°F—can be attained only when the alloy contains 63% tin and 37% lead. This combination is known as an "eutectic" alloy—from the Greek word meaning "easily melted." If the alloy contains a higher percentage of either tin or lead, it passes through an intermediate semi-molten or *plastic* state as it is heated, becoming a liquid at a higher temperature.

When the solder is composed of more than 37% lead—such as 40/60 solder (40% tin, 60% lead)—the lead starts to crystallize out of the solution first as the heated liquid cools. Similarly, if the tin content is above 63%, the tin starts to crystallize first. In either case, the remaining liquid portion of the alloy approaches closer and closer to the 63/37 ratio until the temperature drops to 361°F, at which time the entire mass solidifies. This is the reason solder appears to solidify slowly when it first cools, and then seems to harden instantaneously at a certain point.

Bonding Action. When solder is applied to a metal for which it has an affinity—such as copper—the molten solder actually dissolves some of the surface metal. A new alloy is formed between the metal and the solder, producing a direct metallic chemical bond between the solder and the base metal. It is this characteristic of solder that makes it so valuable in electronic work, for such a bond has very low electrical resistance and is quite resistant to mechanical shocks, vibration, or stress. The strength of the

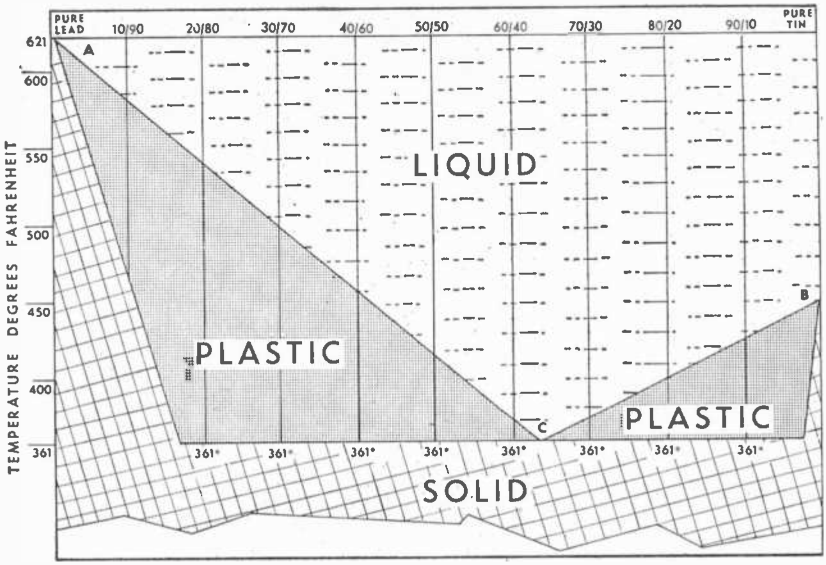


Fig. 1. Solder's melting point can be controlled by varying its tin/lead ratio, since a tin and lead alloy has a lower melting point than either pure lead or pure tin. The melting point shown by lines AC and BC reaches its lowest level with a 63/37 ratio between tin and lead. All non-eutectic alloys pass through a plastic state as they melt.

solder joint depends on the ratio of the solder's tin-lead content, with maximum strength occurring when the tin content is from about 40% to 65% (see Fig. 2).

If a soldered joint will be subjected to severe mechanical stress, it's a good idea to make a strong mechanical connection before you solder. For most purposes, however, this is not necessary. Most experimenters make the mechanical connection just tight enough to hold the wires together while soldering them, allowing the connection to be easily "unsoldered" if necessary.

In order for the all-important metallic bond to be formed, it is essential that the solder alloy contact the surface of the base metal. Dirt, grease, or paint will prevent such contact and result in an improperly soldered joint. For a good job, the metal surfaces to be soldered must be clean.

Another hindrance to good solder-to-base contact is caused by oxygen in the air. Thin oxide crusts which have high electrical resistances and poor heat conduction form on the metal's surface. This oxide film will keep the molten solder away from the base metal and must be removed before proper bonding can take place.

Use of Fluxes. Oxide films are commonly broken up with a corrosive chemical known as a flux. As far as general work is concerned, soldering fluxes are of two basic types: the highly corrosive "acid" flux employed in heavy work and the familiar "rosin" flux used extensively in electrical and electronic soldering.

An acid flux leaves a residue on the joined surfaces. Since this residue has a strong affinity for water, it absorbs water from the air, liquefying and running over the soldered connection. Because it retains its corrosive properties, it can cause damage. In addition, because it is electrically conductive, it can cause shorts.

Rosin flux leaves a residue which is not corrosive and which has high electrical resistance—in fact, it's a pretty good insulator. *Only* rosin-type fluxes should be used to make electrical connections. This point can't be stressed too strongly—most manufacturers of electronic kits automatically void all guarantees if the assembler uses an acid flux for soldering.

Although flux is necessary, it is easy to apply too much or too little. If too little is applied, a poorly soldered connection will result. Too much flux may result in excessive spreading of the solder and an excessive residue. In order that the proper amount of flux may always be used, solders with self-contained fluxes have been developed. The flux is held within a hollow core in the solder wire. Some manufactur-

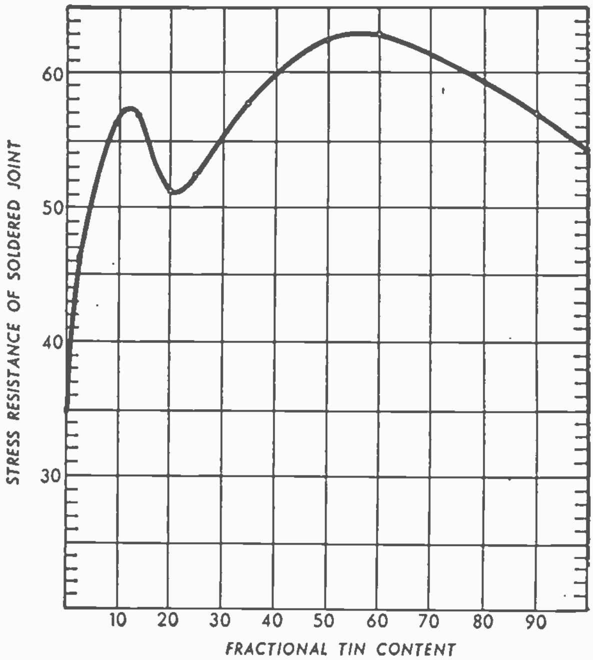


Fig. 2. Effect of increasing tin content on the strength of a solder joint. *(Diagrams courtesy Kester Solder Co.)*

ers use more than one flux core, with three or five cores being the most popular.

Commercially manufactured solder is available in a variety of types, depending on (1) the tin/lead ratio, (2) the diameter and/or shape of the solder, (3) the percentage of flux, if used, (4) the type of flux, and (5) whether it is single- or multi-cored. For radio and electronics work, the most popular kinds are the wire-type, rosin-cored solders, in 40/60, 50/50, or 60/40 alloys, with diameters of from 1/16 to 1/8 inches. The finer-wired solders are used for miniature equipment, such as hearing aids, pocket radios, and so on, while the larger-diameter solder is used for heavier operations such as power connections in transmitters, soldering to metal chassis, etc.

Soldering Tips. Once we know how solder works, it's easy to figure out the best technique to use in soldering—we just apply common sense. First, we know that the surface to be soldered must be clean of dirt or grease. We know, too, that a good mechanical connection must be made before soldering if the joint will be subjected to mechanical stress. And we know that a suitable flux (rosin-type for electronic work) must be used.

The function of the soldering iron is simply to heat the work to the melting point of the solder used. To do this job effectively, the soldering iron tip must be clean, because dirt and corrosion act as heat insulators. Loose dirt and grease can be wiped off a hot soldering tip with a clean damp rag. Corrosion can be removed with the aid of a piece of steel wool or a file.

In addition to being clean, the soldering iron tip must be "tinned." This simply means that there should be a thin coating of molten solder on the tip surface. Tinning prevents an oxide film from forming on the

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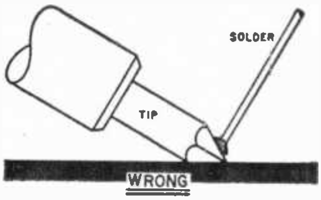
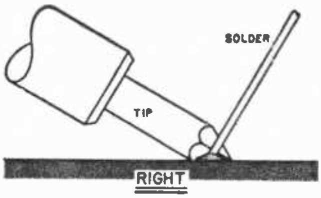


Fig. 3. Good soldering technique calls for the solder to be applied at the junction of the tip of the soldering iron and the joint to be soldered.



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soldering tip and retarding heat transfer.

"Right" and "wrong" soldering techniques are illustrated in Fig. 3. The iron's tip is held flat against the work and the solder is applied at the junction of the tip and the wire to be soldered. Once the solder is applied, the joint must be held stationary while the iron is removed and until the soldered connection cools sufficiently for the solder to solidify. If the connection is disturbed while the solder is in a "plastic" state, the bond may be broken or the solder may solidify in small, high-resistance crystals, giving the joint a "frosty" appearance.

A special soldering technique, often used for soldering aluminum, is illustrated in Fig. 4. Here, a special "aluminum solder" alloy is employed, and the work is heated with a torch flame. A fiberglass brush,

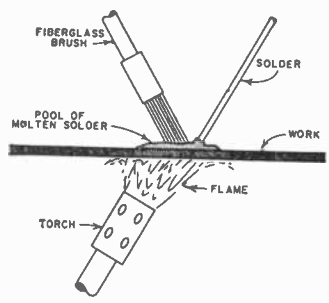

Fig. 4. Special technique often employed in soldering aluminum.

rather than a chemical flux, is used to break up the oxide film on the work's surface. Suitable brushes and aluminum solder are available at most hardware stores.

In practice, the torch flame is applied to the *back* of the work, for the flame itself can serve as a strong oxidizing agent. The solder is melted in a pool, and the fiberglass brush is rapidly rubbed back and forth across the metal surfaces. If two pieces of aluminum are to be joined together, each is "tinned" individually using this technique. Afterwards, the tinned surfaces are clamped together and the torch flame applied to "sweat" the joint together.

Good soldering is absolutely essential to top performance in electronic equipment. And you don't have to be a genius to do an expert job—it's simply a matter of a little knowledge and a little practice. —30—