SOLDERS and SOLDERING

a primer

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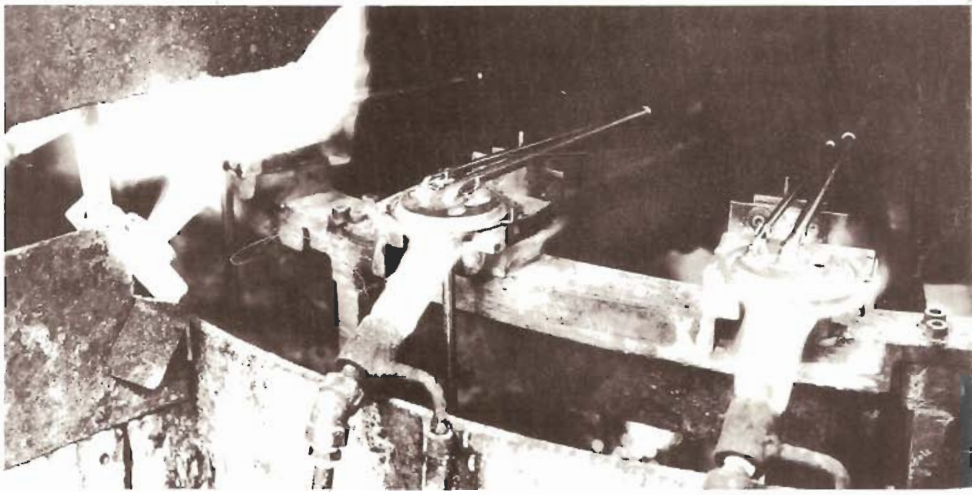
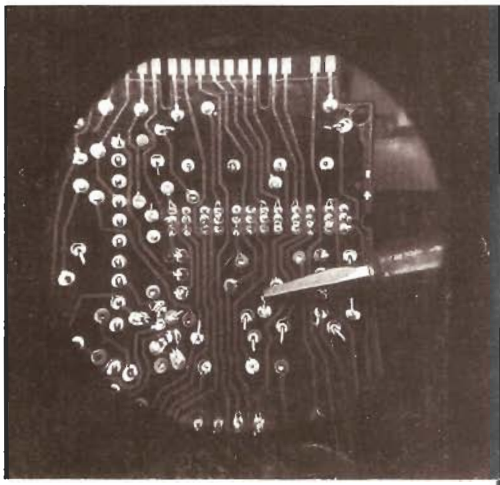




SOLDERS and SOLDER SELECTION

INTRODUCTION

Solder has played a highly significant, but comparatively unrecognized, role in the world's history and it continues to do so today.

The futuristic ideas and designs of Jules Verne to launch a rocket to the moon were not possible at the time he wrote his novel, "Trip to the Moon" in 1865. Solder was available, but the technology did not exist to launch space vehicles. Space age technology didn't arrive until this century, but when it did, solder kept pace as one of the technologies utilized in the manufacture and launch of space vehicles. It played a key role in man's conquest of space.

Three important elements in space technology—miniature electronics, computers and interplanetary communications—are made possible by solder alloys that join the thousands of components in these highly sophisticated products.

Solder also made it possible to produce low cost reliable television and radio sets, car radiators, light bulbs, telephones, typewriters, automotive ignition systems and virtually an endless variety of other business, commercial and industrial products.

Solder is a material used to join metals. Primarily, it is an alloy of tin and lead. The tin component of solder reacts with the metals being joined to facilitate soldering. Solder joints are always made at a temperature less than 800°F, a fact that makes solder the most common method of joining metals without distortion or heat damage to the parts being soldered.

Other solders may contain antimony, silver, zinc, cadmium, indium and bismuth. These solder alloys can, alone or in combination, affect solder properties such as: corrosion resistance, strength, hardness, melting point and service operating temperatures.

There are several important steps in achieving a good soldered joint:

- Design the proper joint for soldering.
- Select the correct solder alloy for the job.
- Select the proper type of flux.
- Clean the surfaces to be joined.
- Apply sufficient heat to the part to make the solder flow properly.
- Remove the flux residue, if necessary.

The solder process is selected over alternative joining methods such as adhesive bonding, welding, brazing, or mechanical joining, because it offers the following combined advantages:

1. The solder process can be easily and economically automated with a low capital expense outlay.
2. A low energy input is required for soldering.
3. Joint reliability is high.
4. Solders with various melting ranges can be selected to fit the application.
5. Sequential assembly is possible.
6. Solders have good thermal and electrical conductivity.
7. Solder joints are impermeable to gas and liquid.
8. Joints are easily repaired and reworked.
9. Precise control is possible over the amount of solder used.
10. A long shelf life is common.
11. A variety of heating methods can be used.
12. Solder alloys can be selected for service in differing environments.

While solder is not noted for its mechanical strength, strong joints can be made through selection of proper solder alloys and proper joint design. For example, joints can be designed to take advantage of the mechanical properties of the base metal by using such techniques as interlocking joints, edge reinforcing, etc.

The choice of whether to use soldering, brazing or welding depends on requirements for joint strength, end use, operating temperatures, and production costs.

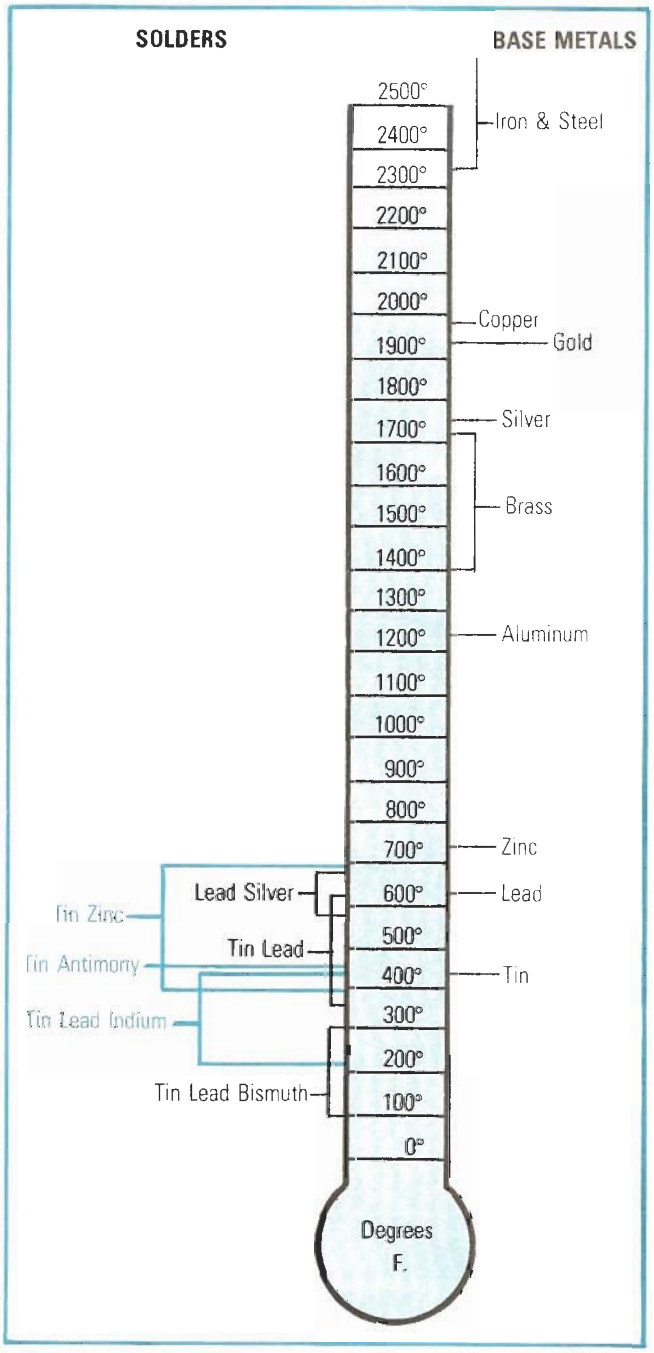


FIGURE 1: Solder Temperature Ranges Compared With Some Base Metal Melting Points.

THE TIN LEAD ALLOYS

Tin lead alloys are the most widely used of all solders. They have the advantage of a low melting range. This makes them ideal for joining most metals by convenient heating methods with little or no damage to heat sensitive parts (See Figure 1).

A pure metal always melts at a single temperature. Most solder alloys melt over a range of temperatures. The temperature at which a solder begins to melt is called the *solidus*. The temperature at which it is completely molten is the *liquidus*. Between these temperatures, part of the solder is molten and part is solid, thus the solder has a pasty consistency.

Figure 2 is a phase diagram showing the solidus and liquidus temperatures for a variety of tin lead solder compositions. It will be noted that at point C the solder both melts and solidifies at a single point as in the case of pure metals. This point is called the *eutectic composition*. Also indicated at point A is pure lead, and at point B, pure tin. The diagram also shows that the addition of tin to lead or lead to tin decreases the liquidus temperature to a minimum—namely, the eutectic.

Care should be taken in specifying the correct solder for the job, since each alloy is unique with regard to its composition and, in general, its properties. Table 1 gives the melting characteristics of some tin lead solders and lists their typical applications. When referring to tin lead solders, the tin content is customarily given first, for example 40/60 refers to 40 per cent tin and 60 per cent lead by weight.

The solders containing less than 5% tin are used for sealing pre-coated containers, coating and joining metals, and for applications where the service temperatures exceed 250°F. At those temperatures, strength is taken care of by design and the solder functions primarily as a seal. The 10/90, 15/85 and 20/80 solders are used for sealing cellular automobile radiators, and filling seams and dents in automobile bodies.

General purpose solders are 40/60 and 50/50. Soldering of automobile radiator cores, plumbing, electrical and electronic connections, roofing seams and heating units are but a few of the typical uses for these solders.

The 60/40 and 63/37 alloys are used where components are heat sensitive and minimum heat should be used to make a solder joint. These alloys also provide the greatest ease and speed of joining. Electronic devices, computers and communications equipment are typical products using these solders.

For the electronics industry, silver is added to tin lead solders to reduce the dissolution of silver from silver alloy coatings. Silver may also be added to improve creep resistance.

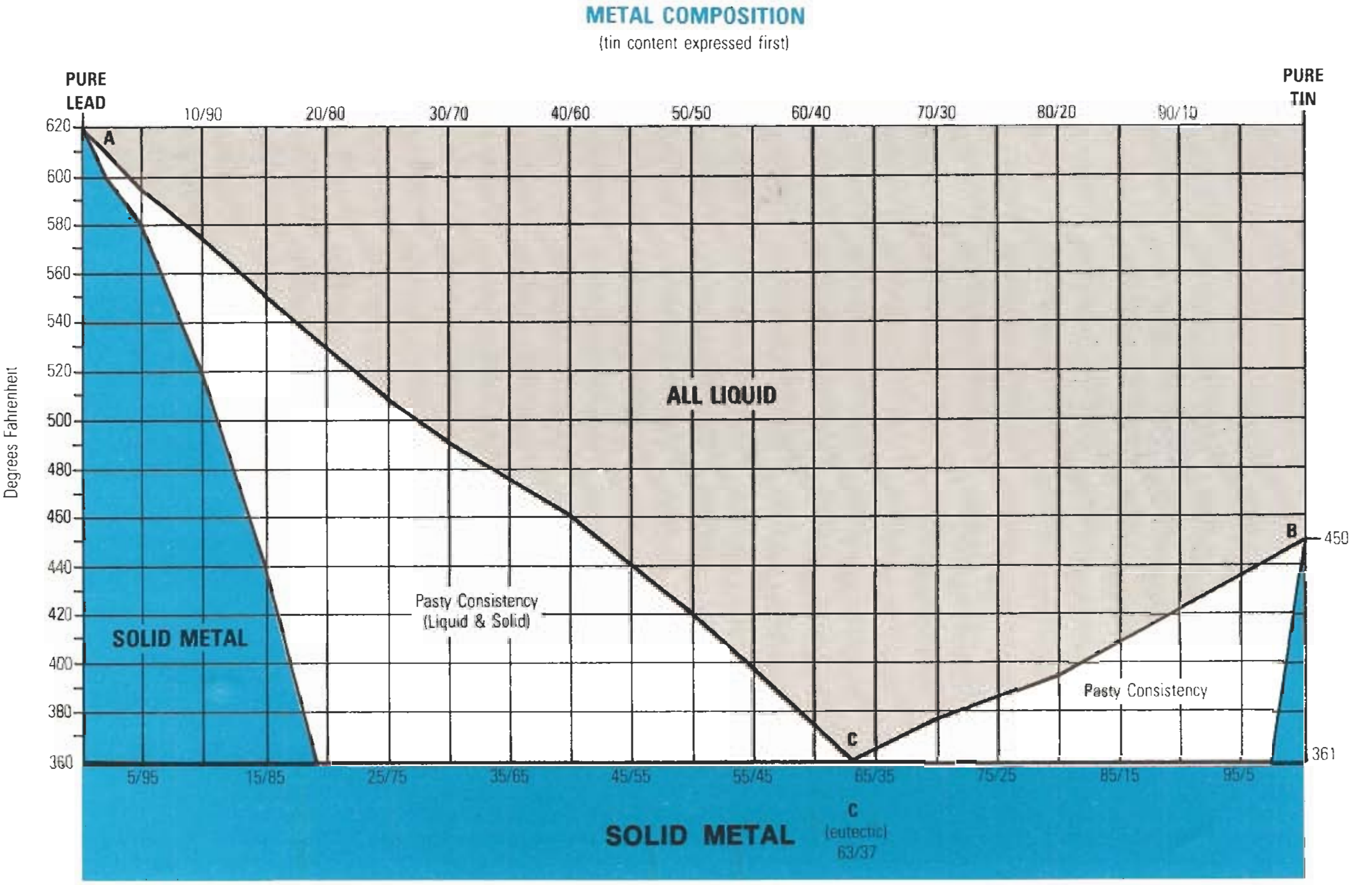
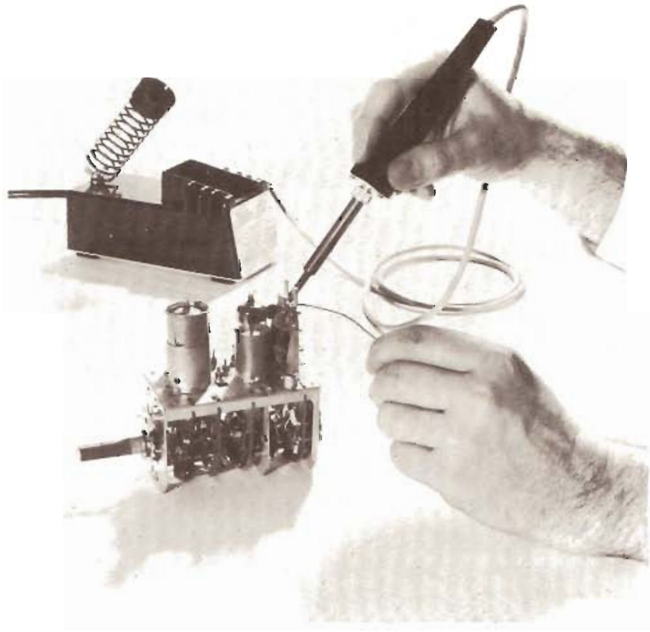
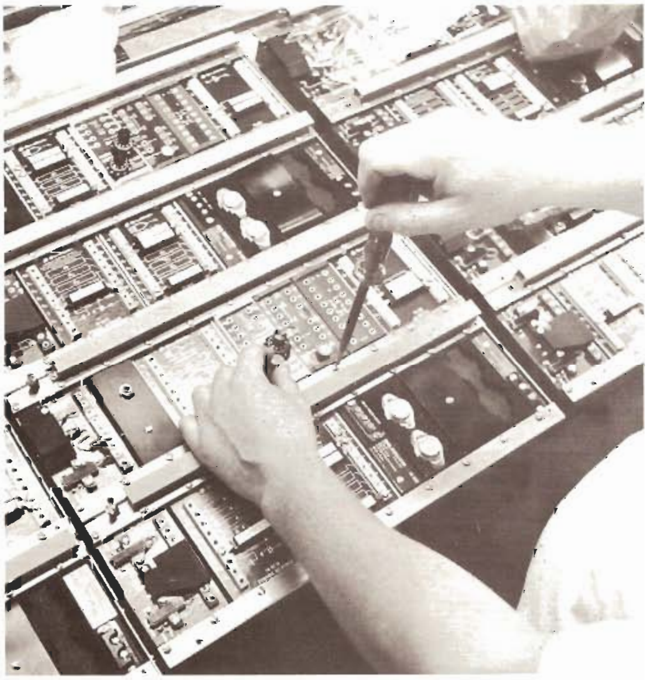


FIGURE 2—Tin Lead Phase Diagram



Serviceman repairs television tuner with solder.

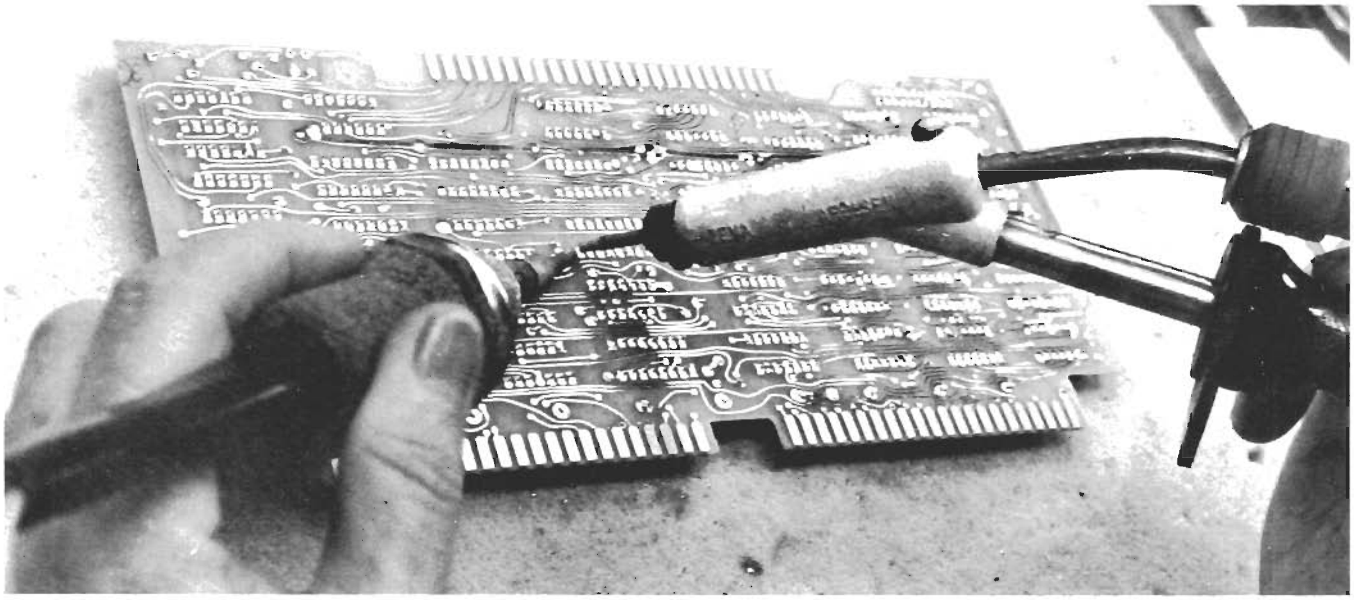


Worker prepares printed circuit boards for dip soldering.

TIN LEAD SOLDERS

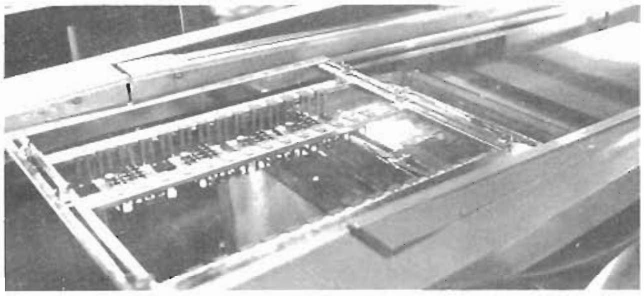
SOLDER ALLOY CLASSIFICATION	COMPOSITION (WT.%)		TEMPERATURE (F)			
	TIN	LEAD	SOLIDUS	LIQUIDUS	PASTY RANGE	USES
2/98	2	98	601	611	10	Side seams for can manufacturing.
5/95	5	95	581	594	13	For coating and joining metals.
10/90	10	90	514	576	62	
15/85	15	85	440	550	110	
20/80	20	80	361	531	170	For coating and joining metals. For filling dents or seams in automobile bodies.
25/75	25	75	361	511	150	For machine and torch soldering.
30/70	30	70	361	491	130	
35/65	35	65	361	477	116	General purpose and wiping solder.
40/60	40	60	361	460	99	Wiping solder for joining lead pipes and cable sheaths. For automobile radiator cores and heating units.
45/55	45	55	361	441	80	For automobile radiator cores and roofing seams.
50/50	50	50	361	421	60	For general purpose. Most popular of all.
60/40	60	40	361	374	13	Primarily used in electronic soldering applications where low soldering temperatures are required.
63/37	63	37	361	361	0	Lowest melting (Eutectic) solder for electronic applications.

TABLE 1



Closeup of printed circuit repair with vacuum desoldering unit.

Tin silver alloys are often used for delicate instrument work and food service equipment where operating temperatures are high. Tin lead silver alloys exhibit good tensile, creep and shear strengths. Some are used for higher temperature bonds in a sequential soldering operation. Fatigue properties are also better than the non-silver alloys. The 1% tin, 97.5% lead, 1.5% silver alloy finds use in cryogenic applications because of its high lead content. It is also used to solder fine copper wires, since copper is not readily dissolved by lead.



Tin antimony and tin silver solders are ideal for joining stainless steel used for food handling equipment and decorative items. Tin antimony solder is used in many refrigeration, plumbing and air conditioning applications because of its good creep and fatigue resistance.

Bismuth-containing solders, the so-called fusible alloys, are used for soldering operations where a low soldering temperature (below 250°F) is required. These alloys require very corrosive fluxes. Indium alloys are primarily used for soldering at low temperatures and where reduction in gold-scavenging is desired. They are also extremely ductile, making them suitable for use in areas where there is a thermal mismatch.

Other special alloys include zinc-aluminum and tin-zinc which are used to solder aluminum in order to minimize potential corrosion in the joint.

SILVER BEARING SOLDERS

COMPOSITION (WEIGHT %) TEMPERATURE (F)

TIN	LEAD	SILVER	SOLIDUS	LIQUIDUS	PASTY RANGE
1	97.5	1.5	588	588	0
62	36	2	354	372	18
10	88	2	514	576	62
96	—	4	430	430	Eutectic
95	—	5	430	473	43

VERY LOW-TEMPERATURE SOLDER

COMPOSITION (WEIGHT %) TEMPERATURE (F)

TIN	LEAD	BISMUTH	SOLIDUS	LIQUIDUS	PASTY RANGE
15.5	32	52.5	203	203	Eutectic
	45	55	255	255	Eutectic
43		57	281	281	Eutectic

TIN ANTIMONY SOLDER

COMPOSITION (WEIGHT %) TEMPERATURE (F)

TIN	ANTIMONY	SOLIDUS	LIQUIDUS	PASTY RANGE
95	5	450	464	14

TIN LEAD INDIUM SOLDERS

COMPOSITION (WEIGHT %) TEMPERATURE (F)

TIN	INDIUM	LEAD	SOLIDUS	LIQUIDUS	PASTY RANGE
50	50		244	257	13
	50	50	356	408	52
37.5	25	37.5	274	358	84

TABLE 2 - Other Solder Alloys

COMMERCIAL FORMS

Solders are commercially available in various sizes, shapes and forms. They can be grouped into several major classifications, as follows:

Pig	Available in 20, 40, 50 & 100 lb. sizes.
Cakes or Ingots	Rectangular or circular in shape, weighing 3, 5 & 10 lb.
Bars	Available in weights from ½ to 2 lb.
Paste	Available as a mixture of solder and flux in paste form in quantities of 1 lb. or more.
Segment or Drop	Wire or triangular bar cut into pieces or lengths of any desired number.
Foil, Sheet & Ribbon	Supplied in various thicknesses and widths.
Wire-Solder	Diameters of .010 to .250 inches on spools, weighing 1, 5, 20, 25 & 50 lbs. or in bulk packs.
Wire-Flux-Cored	Solder can be cored with organic, inorganic or rosin fluxes, .010 to .250 in. diameter on spools, weighing 1, 5, 20, 25 & 50 lb. or in bulk packs.
Preforms	A wide range of custom-designed preform shapes is available. Each shape is a derivative of one or more of the following four most common shapes: wire, punched parts, spheres and flux-coated metal forms.

TABLE 3

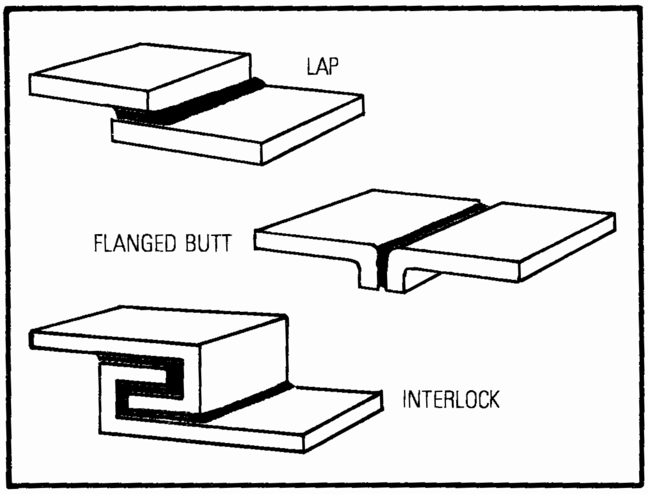


FIGURE 3

JOINT DESIGN

Joints should be designed with the requirements and limitations of solders in mind, and should be shaped so that they fit together properly.

Soldered joints must be planned for the specific purpose they will perform. Such tasks may include providing structural integrity, electrical conductivity, or an effective seal. Additional factors to be considered in joint design are the alloy to be used, the heating method used for soldering, fabrication techniques prior to soldering, the number of items to be soldered, the method of applying the solder, and in-service requirements of the part after joining.

It is well to design so that the strength of a joint is equal to or greater than the load bearing capacity of the weakest member of the assembly. The lack of strength of solder can easily be compensated by shaping parts to be joined so that they engage or interlock, thus the solder is required only to seal the assembly and provide the needed rigidity.

Lap, flanged butt and interlock joints, as seen in Figure 3, are typical designs. Lap and interlock joints should be employed whenever possible since they offer maximum strength.

A particularly significant area of concern in designing joints is to provide for introducing solder into the joint. For example, if joint clearance is too small, this frequently leads to flux entrapment, inadequate solder flow, and a number of voids in the joint. On the other hand, if joint clearances are too wide, capillary flow of the solder filler metal is impaired; or, if the joint is heated too vigorously, the solder runs out or leaves only a bridge at the edge of the opening.

Therefore, optimum clearance in lap joints is approximately 0.003 to 0.005 in. to provide proper capillary flow of the solder and to insure flux removal from the joint.

PRECLEANING AND SURFACE PREPARATION

Oil, film, grease, tarnish and other soil will interfere with soldering. A clean surface is imperative to insure a sound and uniform quality soldered joint. Fluxing alone cannot substitute for adequate precleaning. Therefore, a variety of techniques are used to clean and prepare the surface of metal to be soldered.

The presence of foreign materials—such as grease, oil, paint, pencil markings, cutting lubricants and general atmospheric dirt—will make soldering difficult, if not impossible, because they prevent the soldering process from taking place.

The importance of cleanliness and surface preparation cannot be over emphasized. These steps help insure sound soldered joints, as well as a rapid production rate. Precleaning can also greatly reduce repair work due to defective soldered joints.

The two general methods of cleaning are chemical and mechanical. Most common of these are degreasing, acid cleaning, mechanical cleaning with abrasives, and chemical etching.

- **Degreasing**

Either solvent or alkaline degreasing is recommended for the cleaning of oily or greasy surfaces frequently encountered prior to soldering.

Of the solvent degreasing methods, the vapor condensation of halogenated hydrocarbon type solvents probably leaves the least residual film on the surface. The cold articles to be degreased are suspended above the boiling solvent, causing the vapor to condense on the articles and drain back into the boiling liquid. Only clean, freshly-distilled solvent contacts the material to be cleaned, so there is no recontamination to hinder the degreasing.

The least satisfactory method of degreasing is to rub the articles with a cloth saturated with solvent.

In the absence of vapor degreasing apparatus, immersion in liquid solvents or in detergent solutions is often a suitable procedure. The efficiency of this method of cleaning can be considerably enhanced by incorporating ultrasonic cleaning. This method employs vibrational waves which, through cavitation, promote removal of soils, grit or grease.

Alkali detergents are also used for degreasing. In general, a one to three per cent solution of trisodium phosphate and a wetting agent is satisfactory. All cleaning solutions must be thoroughly washed from the surfaces by steam or water before soldering. Whenever water is used, soft water is preferable, as residues from hard water may interfere with the soldering.

These cleaning methods are especially designed for substantial volume and should be thoroughly investigated as to the proper safety precautions to follow and their suitability for the application.

- **Acid Cleaning**

Acid cleaning, or "pickling," is used to remove rust and oxide scale from the metal. This provides a chemically clean surface. Hydrochloric, sulfuric, orthophosphoric, nitric and hydrofluoric acids can be used, either singly or mixed, for acid cleaning. Hydrochloric and sulfuric acid are the most commonly used. An inhibitor is sometimes used to prevent pitting once the scale has been removed.

After pickling, if droplets of water show on the metal surfaces, there may still be traces of grease or other contaminants on the surface which should be removed before proceeding. The articles should be thoroughly washed in hot water after pickling and dried as quickly as possible.

For many electronic applications, such as printed circuit boards and component leads, special, mild proprietary surface cleaners and solutions are available.

- **Mechanical Preparation With Abrasives**

A commonly used method of cleaning is abrasion, which consists of grit or shotblasting; mechanical sanding or grinding, filing or hand sanding; cleaning with steel wool; wire brushing; or scraping with a knife or shave hook.

For best results, cleaning should extend beyond the joint area. A simple solderability test should be performed following abrasive cleaning. Care should be taken to avoid embedding abrasive grit in the surface since this will affect solderability.

- **Plating**

Plating can be used as a surface preparation process. Tin lead, tin, copper, cadmium, gold, silver, tin nickel and other commonly used materials can provide a suitable surface for soldering.

All precleaning and surface preparations are intended to produce a surface suitable for soldering. Solderability is the term used to define the capacity of a surface to be soldered under specific manufacturing parameters that include solder alloy, solder flux, time and temperature of the soldering process.

FLUXING

One of the most critical steps in soldering is the selection of the proper flux to ensure a satisfactory soldered bond.

When exposed to the atmosphere, most metals react to form compounds on their surface. The most common compounds formed are oxides, sulfides, and carbonates. The thickness of the film formed by these compounds is usually determined by the length of time during which the metal has been exposed to the atmosphere. Increased amounts of either moisture or heat, or a combination of both, tend to increase the compound build-up even though in many cases it may not be visible.

The rate of formation and the tenacity of these surface compounds vary with each base metal and are what determines the ease with which each metal can be soldered. This is because the surface compound forms an effective insulating barrier that prevents the metals from touching each other. As long as this non-metallic barrier is present on the surface of metals, it is not possible to make metal-to-metal contact such as that required in soldering. Therefore, it is necessary to remove the non-metallic compound film from the surface of metals and keep it removed during the soldering operation in order to insure that the "clean" metal surface will permit the intermetallic solvent action of soldering to take place.

The chemical agent used to remove compounds from the surface of metals during the soldering process is called a soldering flux. Ideally, the flux selected should be chemically active enough to remove the surface compounds; stable enough to prevent oxidation during soldering; and leave a residue which is non-corrosive and non-conductive. No such universal flux exists which meets all of the above requirements for every metal. It is therefore, necessary to choose the flux for each special application, and design the process of soldering to assure the most economical end result consistent with the reliability requirements of the product. For example, if aluminum, high alloy steel or stainless is to be soldered, it may require a very corrosive flux because these metals form a tenacious oxide film. Since such fluxes leave a corrosive residue, it is usually necessary to remove the flux residue after the soldering operation. If that is not economical or possible, it may be necessary to first coat the base metal with solder or another solderable metal and then to assemble and solder using a mild, non-corrosive flux.

There are three general classes of fluxes in common use. Listed in order of activity they are:

Inorganic Fluxes (most active)

Inorganic type fluxes are comprised of one or more inorganic salts such as zinc chloride and ammonium chloride dissolved in water. They are the most corrosive and conductive of all fluxes and are effective on all common metals except aluminum and mag-