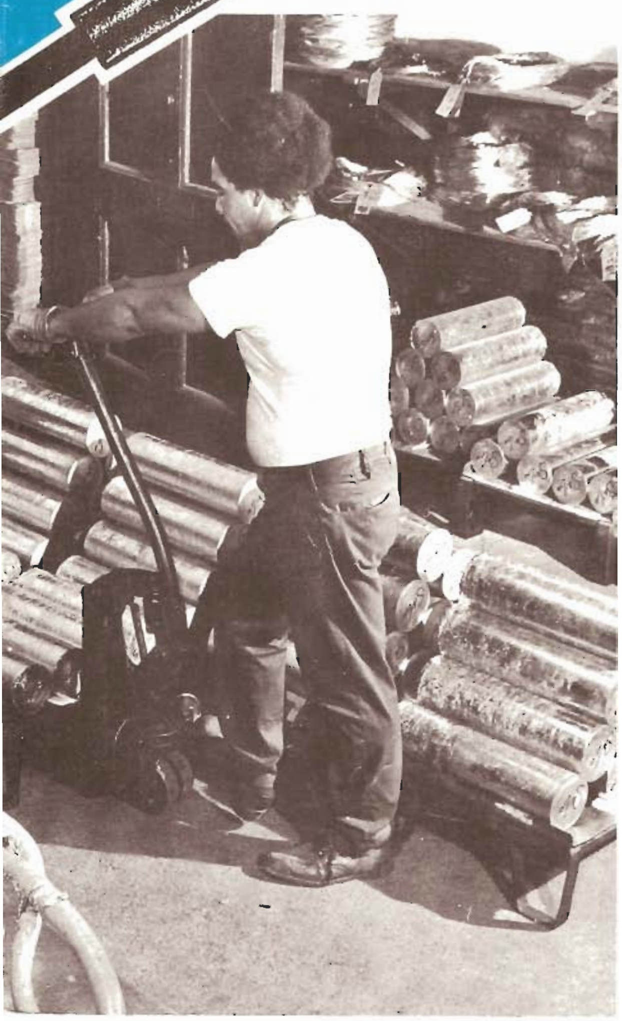
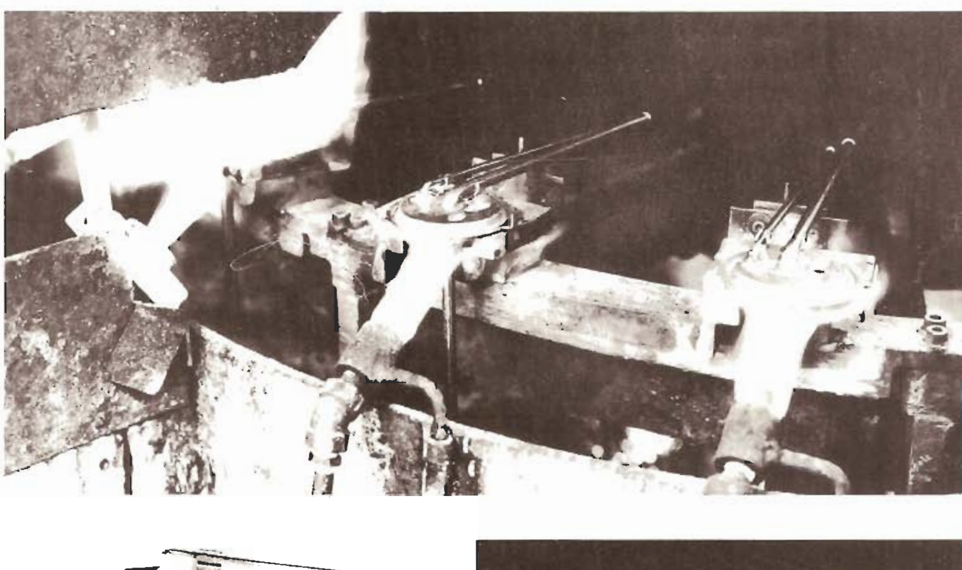
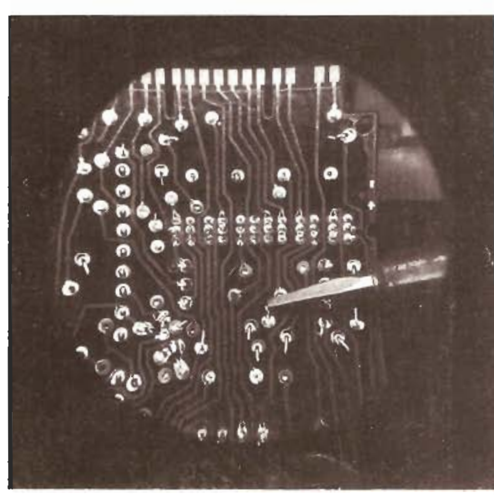
SOLDERS and SOLDERING

a primer

Federated Genco Limited
4480 HARVESTER ROAD
P.O. BOX 5031, BURLINGTON, ONT. (416) 637-5203
1400 NORMAN STREET, LACHINE, QUÈ. (514) 637-3591







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.

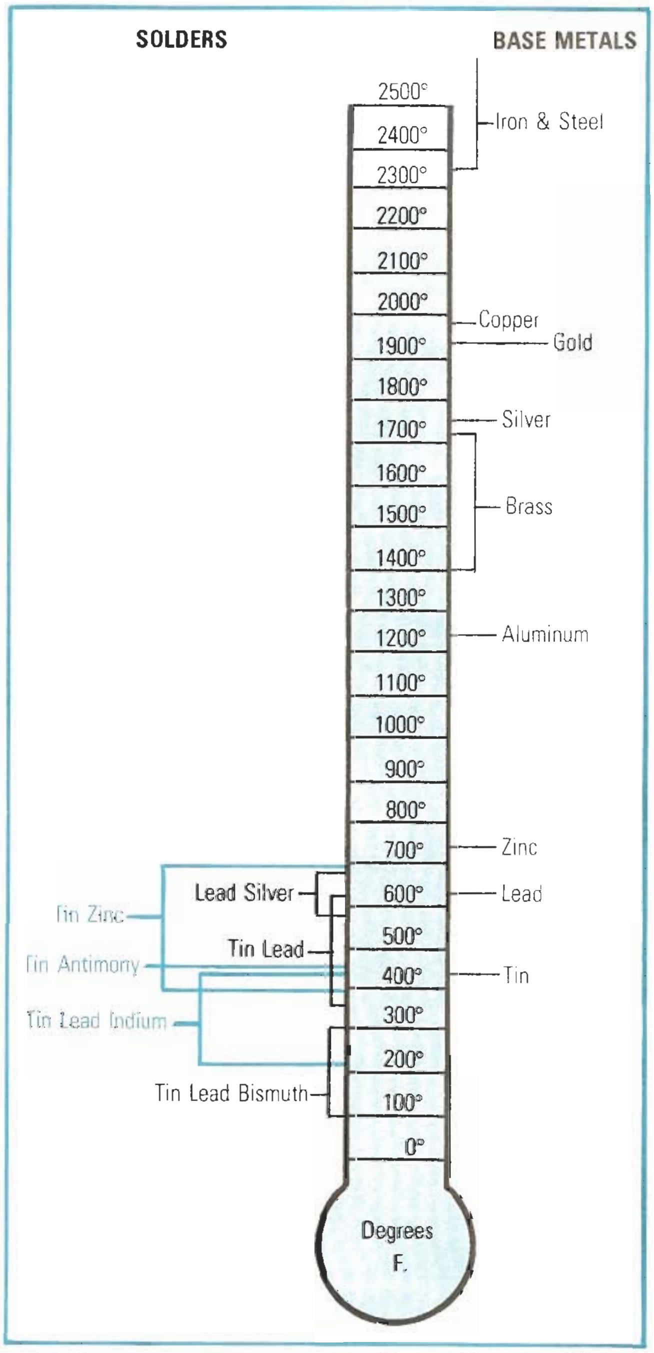


FIGURE 1: Solder Temperature Ranges Compared With Some Base Metal Melting Points.

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.

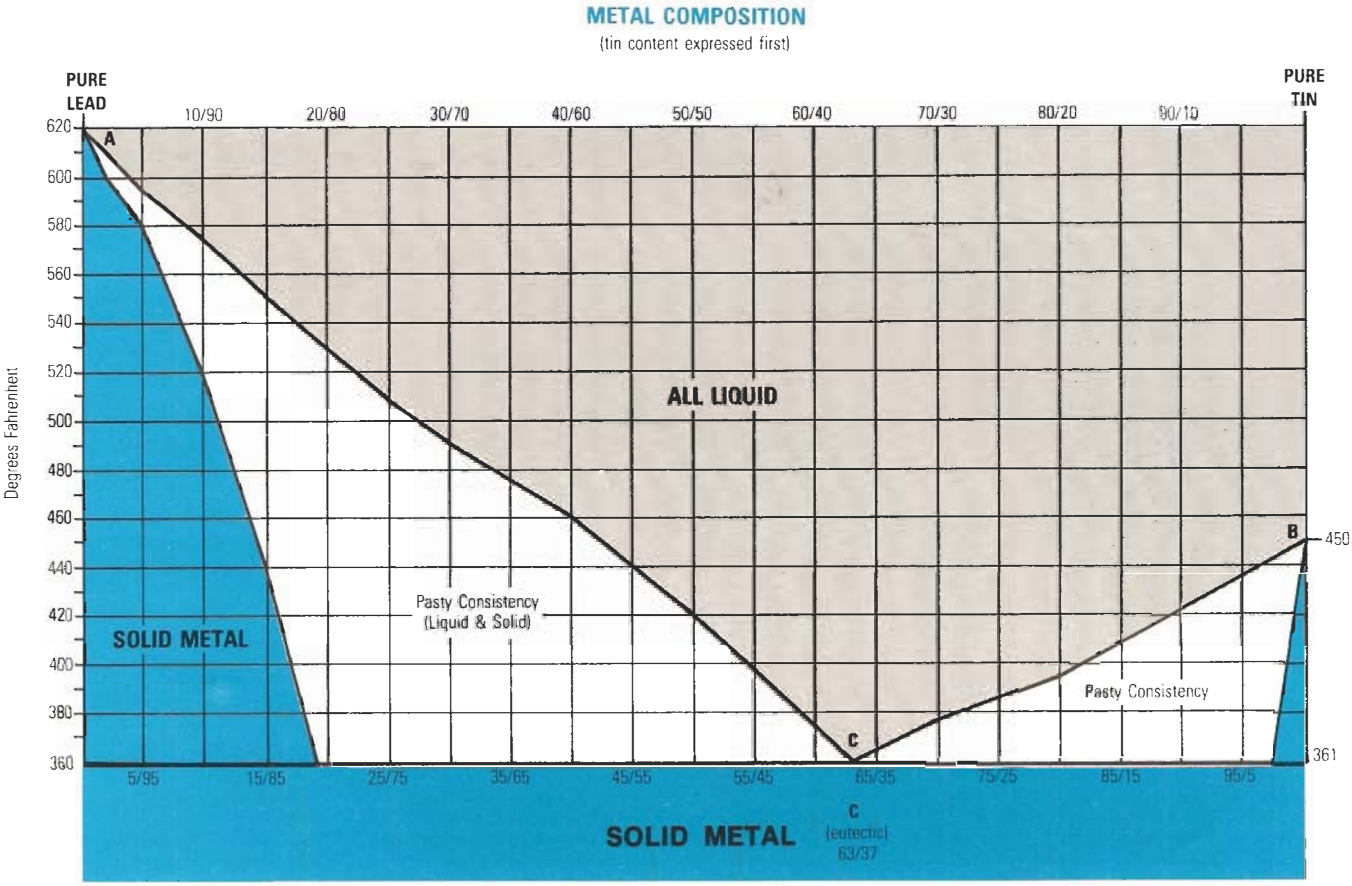
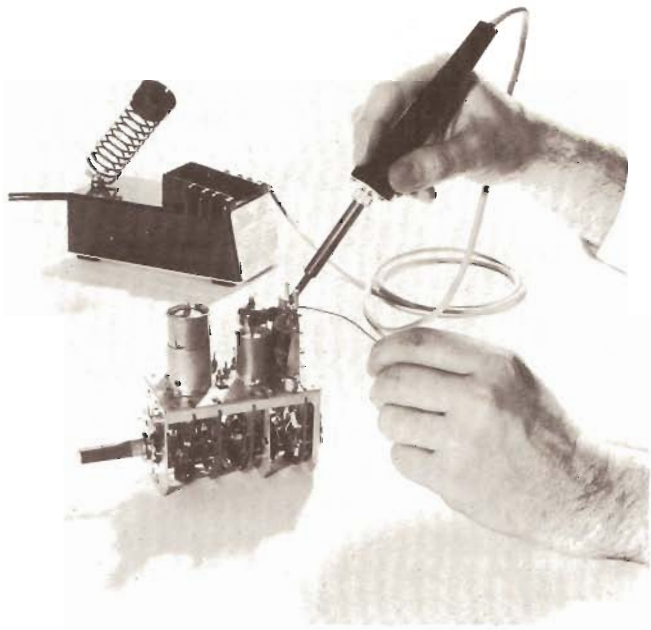
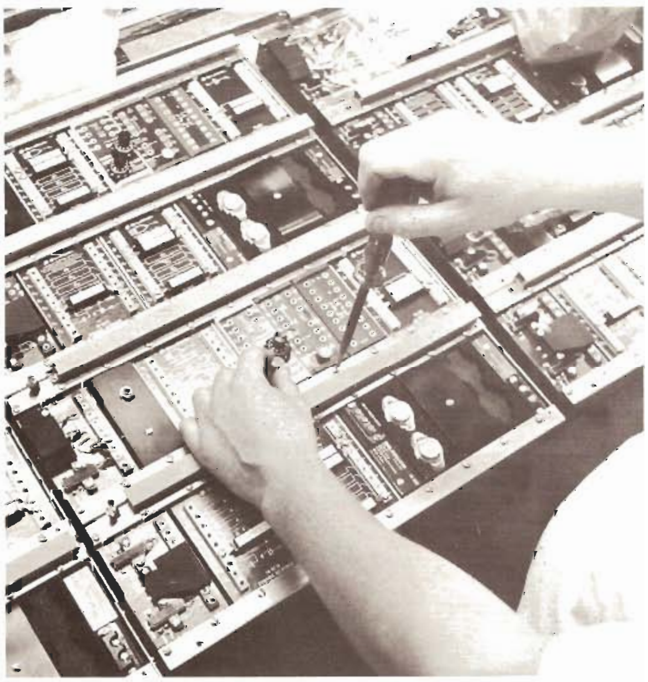


FIGURE 2—Tin Lead Phase Diagram



Serviceman repairs television tuner with solder.

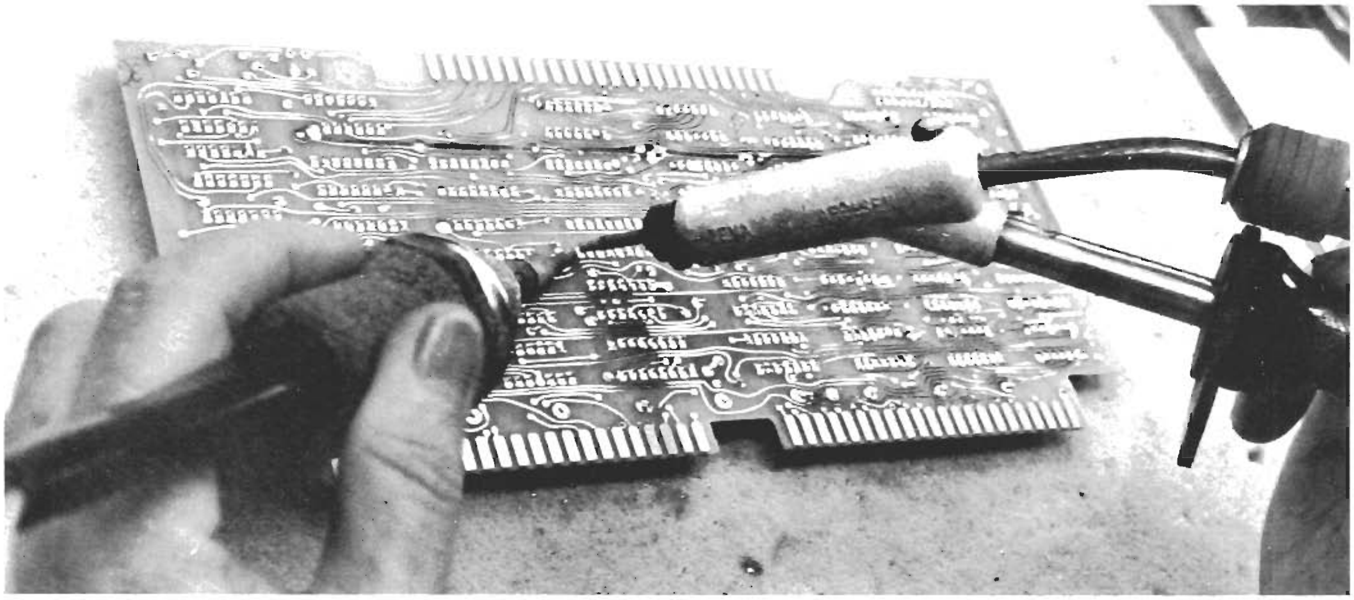


Worker prepares printed circuit boards for dip soldering.

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



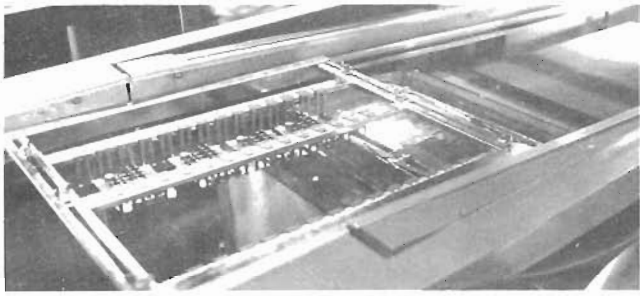
Closeup of printed circuit repair with vacuum desoldering unit.

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

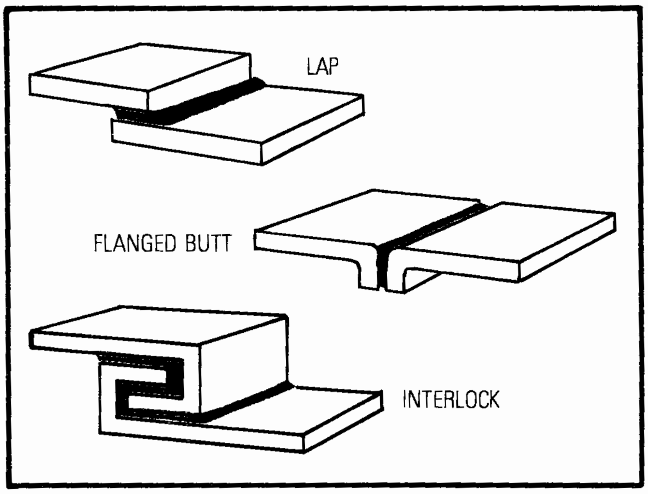


FIGURE 3

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 magnesium. Such fluxes are used for non-electrical soldering and are not suitable for use on electrical assemblies because they are highly corrosive and conductive. The residue should be completely removed with water. A more thorough cleaning method involves dipping the parts in a 2% hydrochloric acid bath to solubilize the flux residue, followed by a water rinse.

Organic Fluxes (moderately active)

Organic type fluxes are comprised largely of organic acids such as glutamic acid or stearic acid dissolved in water or alcohols. These fluxes are less active than inorganic fluxes and more active than rosin fluxes and they can be used for some electrical soldering.

Rosin Fluxes (least active)

Rosin is the base for fluxes used for electronic soldering. It is produced from pine trees and is unique because it becomes active as a flux when heated and returns to an inactive state when cooled. Within the family of rosin fluxes there are three recognized classifications:

Activated Rosin–rosin fluxes to which small amounts of strong activating agents have been added to improve the fluxing action.

Mildly Activated Rosin–rosin fluxes to which have been added mild activating agents to improve the fluxing action.

Non-Activated Rosin–rosin fluxes with no activating agents.

Rosin fluxes find their greatest applications in high reliability electronic soldering because the residues are the least corrosive and conductive of all of the flux types.

Fluxes can be supplied as liquid, paste, solid, or combined with solder, in core solder, or paste solder.

Table 4 may be used in selecting fluxes for soldering base metals. Where more than one flux is effective on a given base metal it is good practice to use the mildest flux. Soldering of aluminum is a difficult process and requires special fluxes and alloys.

METALS	SOLDERABILITY	ROSIN FLUXES Non-Activated	ROSIN FLUXES Mildly Activated	ROSIN FLUXES Activated	ORGANIC FLUXES Water Soluble	INORGANIC FLUXES Water Soluble	SPECIAL FLUX AND/OR SOLDER
PLATINUM GOLD COPPER SILVER CADMIUM PLATE TIN (Hot Dipped) TIN PLATE SOLDER PLATE	Easy to Solder	√	√	√	√	Not recommended for electrical soldering	
LEAD NICKEL PLATE BRASS BRONZE RHODIUM BERYLLIUM COPPER	Less Easy to Solder	Not Suitable		√	√	√	
GALVANIZED IRON TIN-NICKEL NICKEL-IRON MILD STEEL	Difficult to Solder	Not Suitable			√	√	
CHROMIUM NICKEL-CHROMIUM NICKEL-COPPER STAINLESS STEEL	Very Difficult to Solder	Not Suitable			Not Suitable	√	
ALUMINUM ALUMINUM-BRONZE	Most Difficult to Solder	Not Suitable			Not Suitable		√
BERYLLIUM TITANIUM	Not Solderable						

TABLE 4 Metal Solderability Chart and Flux Selector Guide

THE SOLDERING PROCESS

In addition to surface preparation, solder selection, and fluxing, another important part of the soldering process is choice of the best heating method. Available methods include:

The Soldering Iron or Bit

A common method of soldering is by means of a soldering iron or bit. They may be heated electrically, by direct flame, or by oven.

Because soldering is a heat transfer process, the maximum surface area of the heated tip should contact the base metal during soldering. In making a joint, the solder itself should not be melted upon the tip of the iron. If flux cored wire is being used, such practice will destroy the effectiveness of the flux.

A large variety of size and design irons is available, from a small pencil size to special irons or bits which weigh five pounds or more. The selection of the iron depends on the task and how much heat is needed at the joint with the heat recovery time of the iron being fast enough to keep up with the job.

Plain copper bits and iron coated bits are commonly used. Both types must be kept well tinned (coated with molten solder) during use. Oxidized iron tips should never be filed because the thin electrocoating will be removed and the tip ruined.

Regardless of the way in which they are heated, bits perform the following functions:

1. Store and conduct heat from the heat source to the parts being soldered;
2. Bring the workpiece to the soldering temperature;
3. Store molten solder;
4. Convey molten solder;
5. Withdraw surplus molten solder.

Flame or torch soldering

Where fast soldering is necessary, flame is frequently used. Flame temperature is controlled by the fuel mixture used. Any fuel gas burned with oxygen will give the highest flame temperature possible with that gas. The highest flame temperatures are attainable with acetylene and lower temperatures with propane, butane, natural gas and manufactured gas.

Hot-dip soldering

When conducted properly, dip soldering may be very useful and economical inasmuch as an entire assembly, comprising any number of joints, can be soldered merely by dipping in a bath of molten solder. It is necessary, however, to use jigs, or fixtures to contain the unit and keep the proper clearance at the joint until solidification of the solder takes place.

The molten bath supplies both the heat and the solder necessary for completing the joint. The soldering pot capacity should be large enough so that at a given rate of production the units being dipped will not appreciably lower the temperature of the solder bath.

A preliminary treatment of the assembly being soldered, such as degreasing, cleaning and fluxing is also required before dipping.

Electronic components are commonly soldered to printed circuit boards by a process called wave soldering. This approach lends itself to automatic mass soldering. It is a continuously pumped crest of solder that peaks at the printed circuit board. Another method is "drag" soldering which handles the job of soldering by using a bath into which the board is automatically dipped with controlled time.

Both of these techniques may be highly automated incorporating a fluxing station, preheating or drying station, soldering station, and cleaning. Automatic mass soldering speeds can range from two to 16 feet per minute. Modern mass soldering machines offer adjustable tracks, variable carriers, and a variety of options to accommodate a large cross section of tasks to be accomplished.

Induction heating

The only requirement for a material that is to be induction soldered is that it be an electrical conductor. The rate of heating, however, is dependent on the induced current flow. The distribution of heat obtained with induction heating is a function of the induced current frequency. The higher frequencies concentrate the heat at the surface of the work piece.

Three types of equipment are available for induction heating: the vacuum tube oscillator, the resonant spark gap, and the motor generator unit.

Induction heating is generally applicable for soldering operations with the following requirements: 1) large-scale production; 2) application of heat to a localized area; 3) minimum oxidation of surface adjacent to the joint; 4) good appearance and consistently high joint quality; 5) simple joint design which lends itself to mechanization.

Resistance heating

In resistance heating, the work to be soldered is placed either between a ground and a movable electrode or between two movable electrodes to complete an electrical circuit. Heat is applied to the joint both by the electrical resistance of the metal being soldered and by conduction from the electrode, which is usually carbon.

Production assemblies may utilize multiple electrodes, rolling electrodes or special electrodes, depending on which will be advantageous with regard to soldering speed, localized heating and power consumption.

Resistance soldering electrode bits cannot generally be tinned and the solder must be fed directly into the joint.

Oven heating

Oven heating should be considered when entire assemblies can be brought to the soldering temperature without damage to any of the components; when production is sufficiently great to allow expenditure for jigs and fixtures to hold the parts during soldering; and when the assembly is complicated in nature, making other heating methods impractical.

Infrared Heating

Heating by radiative transfer is commony called infrared, or IR heating. The most common sources of IR for soldering applications are heated filaments. The quartz-iodine, tungsten filament lamp is widely used because it is very stable and reliable over a wide range of temperatures.

In general, infrared heating systems are simple and inexpensive to operate. Variations in the condition of the solder surface can be compensated to some extent by adjusting the heating power, but one of the most critical operating parameters is surface conditions. Advantages are: process repeatability, ability to concentrate or focus the energy with reflectors and lenses, economy of operation and lack of contact with the workpiece.

Ultrasonic Soldering

Ultrasonic soldering can be considered a form of dip soldering in which the workpiece is immersed in a tank of molten solder. When a properly designed transducer (source of ultrasonic energy) is energized in a bath of molten solder it produces cavitation in the region around the end of the transducer. Aided by the solvent action of the molten tin, the cavitating solder actually scrubs, attacks and removes the surface compounds and soils found on the workpiece much as a flux would do in the usual solder operation.

After cleaning, which takes only a fraction of a second, solder wets the clean metal and is deposited on it. Thickness of the deposit is a function of immersion time and solder temperature.

Ultrasonics allows fluxless soldering and enables the soldering of metals otherwise considered difficult to solder such as Kovar, nickel alloys and aluminum.

CASE HISTORIES

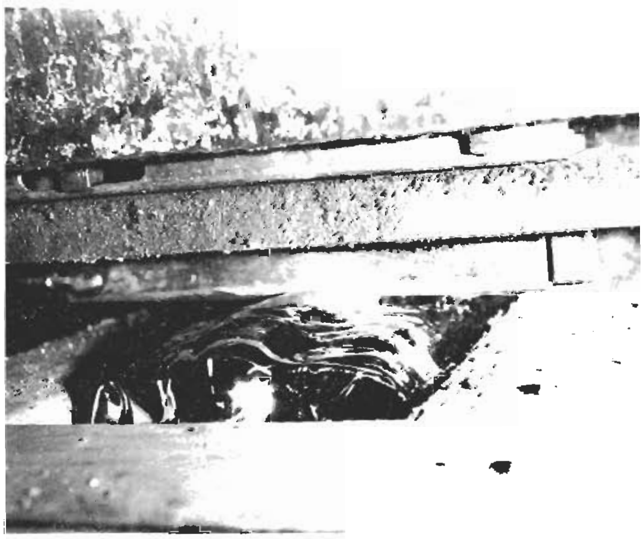
IN COMMUNICATIONS . .

A Good Connection with Solder

Today's telephones are a vast improvement over the crudely-joined voice communications device that carried Alexander Graham Bell's request: "Mr, Watson, come here, I want you" to mark one of the first telephone messages to be transmitted. Since that brief, hard-to-hear message was communicated at Boston in 1876, telephones have improved immensely.

Bell's first city-to-city messages were transmitted over old telegraph lines which frequently had rusty wire connections. Such joints caused considerable voice transmission problems until soldered joints came into use. And from that time until now, soldered joints have continued to play a major role in producing increasingly efficient, virtually maintenance-free telephones. In addition, modern sophisticated soldering techniques have been developed to help mass produce these reliable telephone components at the most economical cost possible.

Typical is this wave soldering operation at the Kearny, New Jersey plant of Western Electric Co., the manufacturing arm of Bell Telephone. A special wave soldering system is used there to join electronic components of desktop telephone units which provide interoffice communications in industrial plants, offices, etc. One of the components the system was designed to join and connect is an inch-thick, plug-type printed circuit board consisting of a printed wiring board, miniature relays, transistors, and other electronic components.



In production, the circuit boards are loaded upside down on the top side of a specially designed conveyor belt and then they receive two fluxings and two solderings. First a thin coating of mildly activated rosin alcohol flux is applied before the board enters a single wave of solder which fills all holes in the board with a 60/40 tin lead solder. The boards then pass through a second, heavier flux operation and four successive solder waves that selectively deposit solder to the desired thickness. Following this, the boards pass through an automatic cleaning and drying operation before removal from the belt. They are then given a thorough quality control inspection, both visually and electronically.

Western Electric produces the boards at its Kearny, N.J., plant at the rate of about 50,000 units per week.

IN TRANSPORTATION . . .

Solder Provides A Smooth Profile

For more than 75 years it has been standard practice in the automotive industry to use the full range of solder's versatility to enhance the beauty of the car body by filling seams with "body solder."

What's little known is that a similar practice is followed to seal seams and improve the aerodynamic properties of those gleaming new stainless steel Amtrak railway passenger cars being produced by The Budd Company in Philadelphia. Every car in the $192,000,000 fleet of new Amtrak equipment, as well as each of the new Long Island Railroad cars produced by Budd, has a longitudinal seam of 50/50 tin lead solder on either side of the roof. In addition, for aesthetic reasons, as well as cost, solder is frequently used to seal the seams around the end cap of each car.

Designed for maximum passenger comfort, as well as low maintenance and high performance, each car undergoes numerous quality control checks and inspections during construction. Besides blending well with the stainless steel roof and sides of the car, the solder seam serves another function—it serves to assure a watertight joint where the stainless roof overlaps and has been welded to the stainless side panel of the car. As a final check to be absolutely sure no seam, whether calked, welded or soldered, will leak when the car is in service, the entire railroad car is sprayed with 1,280 gallons of water per minute prior to leaving the plant, while every seam and joint is inspected for leaks.

The Budd Company produces over 300 railroad cars of all types per year, e.g., rapid transit; commuter and intercity or mainline types. Shown here is one of the 492 locomotive-hauled or mainline type cars Budd is building at its assembly line in Philadelphia.

IN METALWORKING . . .

Solder Puts The "ZIP" In Zippo Lighters

Small, wafer-thin lead alloy solder preforms have played a major role in helping Zippo lighter achieve world-wide fame for lighting in wind, rain or snow; under guarantee of free repair.

Produced by the Zippo Manufacturing Co. of Bradford, Pennsylvania, the Zippo lighter is the best-known product of its kind in the world. It is owned by presidents, kings, world statesmen, military men and women, corporate heads, and millions of others.

The basic Zippo line consists of two standard sizes: a slim model, that is about 1¼-in. wide and 2-¼-in. high; and a standard model that is approximately 1½-in. wide and 2¼-in. high.

According to Ray Uhler, Zippo's plant manager, tin lead solder plays one of the most critical roles in the efficient manufacture and operation of the faultless lighters. He says this is why the soldering operation includes very stringent quality control procedures.

Uhler explains that solder preforms literally help put the "zip" in Zippo lighters. The preform is used to solder-join and seal a plate to the inner case of the lighter. When this case is inserted into the outer shell of the lighter, the resulting envelope forms a sealed enclosure that contains the wick and the absorbent packing to hold that fluid used to fuel the lighter. Therefore, the soldered plate must form an airtight and leak-proof seal with the inner case. Otherwise rapid evaporation would waste the fuel and require too frequent refilling.

All solder preforms used in the joining process are 50/50 tin lead alloy. The preforms vary in length and width depending on whether slim or regular-size lighters are in production. Regular-size preforms are .015-in. thick, while the thin-size preform is .017-in. thick. The thickness variation is due to the difference in gauge of the stainless steel used for the two cases.

About 40% of Zippo's sales volume comes from more than 27,000 commercial accounts, comprising some of the biggest corporate names in industry. They regularly order Zippos in huge lots to serve as premiums, promotional handouts, employee awards and sales incentives. Many times the company emblem is soldered on the face of the lighter. "If you solder an emblem on, you know it's going to stay," says plant manager Uhler. "If the emblems are epoxy-joined to the face of the lighter, you know that sooner or later, they will come off. We've tried other joining techniques, too, but we always come back to solder because it's the best and most economical joining method we've found."

IN AUTOMOTIVE . . .

Solder Keeps Tubing on Target

Millions of truck, automobile and bus drivers face a potentially dangerous situation after every rain or snow storm: how to keep windshields clean enough for good visibility when the highway is still wet and there's not enough moisture for windshield wipers to effectively wipe away the splatter of dirt thrown onto windshields from the wheels of passing traffic.

Drivers of modern automobiles seldom have to worry about such things for long, because a press of the wiper knob activates an automatic window-wash system to clean the window.

An inherant part of this invisible, "good visibility" system is the small metal tubing that carries the system's liquid supply from under the hood to the spray nozzle at the base of the windshield.

While most people are familiar with the window-wash system, very few are aware that tin lead solder plays an important role in the efficient performance of the system. When engineers were designing the system, they knew a technique had to be devised to join the fastener brackets to the tubing in a permanent manner. The material that joined the brackets to the tubing would be subjected to high operating temperatures as well as below-zero temperatures and winter elements. In addition, the material had to be corrosion resistant and applied with mass-production techniques since more than a million of the units are made by one company each year.

According to Jonesville Products, Inc., Jonesville, Mi., one of the country's leading producers of automobile windshield washing systems, a 60/40 tin lead solder alloy was selected to join the fastener brackets to the tubing because it not only lends itself to mass production techniques, but is strong enough to withstand the constant vibration encountered when vehicles are in motion. The solder also withstands extremes in heat and cold and is corrosion resistant.

The windshield washer tubing is produced for most major American automobile manufacturers. There are various configurations in the shape of the tubing and the location of the fastener plates. All tubing is joined with acid core solder preforms. In the production process, the preforms are laid manually in special fixtures.

With the solder preform, the cold rolled steel clip and the washer tube in place on a turntable conveyor, the units proceed through an array of gas-fired flames that achieve proper soldering temperatures for joining the clips to the tubing. After the assemblies have been soldered, they pass through a water spray mist which removes excess flux.

Bob Sorrell, vice president of Jonesville Products, says, "Soldering readily lends itself to mass production techniques to enable us to produce high volume of up to a million and a half units per year."

Two solder preforms shown in position on either side of windshield washer tubing before soldering to support clip.

ELEMENT	SYMBOL	ELEMENT	SYMBOL
Aluminum	Al	Iron	Fe
Antimony	Sb	Lead	Pb
Arsenic	As	Nickel	Ni
Bismuth	Bi	Silver	Ag
Cadmium	Cd	Sulfur	S
Copper	Cu	Tin	Sn
Gold	Au	Zinc	Zn
Indium	In		

TABLE 5—Some Elements and Their Chemical Symbol

Composition percent														
Alloy Grade	Tin Desired	Lead, Nominal	Antimony			Silver			Bismuth, max	Copper, max	Iron, max	Aluminum, max	Zinc, max	Arsenic, max
			Min	Desired	Max	Min	Desired	Max						
70A	70	30	...	...	0.12	...	...	...	0.25	0.08	0.02	0.005	0.005	0.03
70B	70	30	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.03
63A	63	37	...	...	0.12	...	...	...	0.25	0.08	0.02	0.005	0.005	0.03
63B	63	37	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.03
60A	60	40	...	...	0.12	...	...	...	0.25	0.08	0.02	0.005	0.005	0.03
60B	60	40	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.03
50A	50	50	...	...	0.12	...	...	...	0.25	0.08	0.02	0.005	0.005	0.025
50B	50	50	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.025
45A	45	55	...	...	0.12	...	...	...	0.25	0.08	0.02	0.005	0.005	0.025
45B	45	55	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.025
40A	40	60	...	...	0.12	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
40B	40	60	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
40C	40	58	1.8	2.0	2.4	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
35A	35	65	...	...	0.25	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
35B	35	65	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
35C	35	63.2	1.6	1.8	2.0	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
30A	30	70	...	...	0.25	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
30B	30	70	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
30C	30	68.4	1.4	1.6	1.8	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
25A	25	75	...	...	0.25	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
25B	25	75	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
25C	25	73.7	1.1	1.3	1.5	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
20B	20	80	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
20C	20	79	0.8	1.0	1.2	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
15B	15	85	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
10B	10	90	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
5A	5[d]	95	...	...	0.12	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
5B	5[d]	95	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
2A	2[e]	98	...	...	0.12	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
2B	2[c]	98	0.20	...	0.50	...	...	...	0.25	0.08	0.02	0.005	0.005	0.02
2.5S	0[f]	97.5	...	...	0.40	2.3	2.5	2.7	0.25	0.08	0.02	0.005	0.005	0.02
1.5S	1[g]	97.5	...	...	0.40	1.3	1.5	1.7	0.25	0.08	0.02	0.005	0.005	0.02
95TA	95	0.20 max	4.5	5.0	5.5	...	...	...	0.15	0.08	0.04	0.005	0.005	0.05
96.5TS	96.5	0.20 max	0.20	...	0.50	3.3	3.5	3.7	0.15	0.08	0.02	0.005	0.005	0.05

[a] Analysis shall regularly be made only for the elements specifically mentioned in the above table.

[b] The chemical requirements of SAE specififcations Nos. 1A, 2A, 2B, 3A, 3B, 4A, 4B, 5A, 5B, 6A, and E-07 conform substantially to the requirements for alloy grade Nos. 45B, 40B, 40C, 30B, 30C, 25B, 25C, 20B, 20C, 15B, and 2.5S, respectively.

[c] Federal specifications are similar to the above alloy grade Nos. 70B, 63B, 60B, 50B, 40B, 35C, 30C, 20C, 2.5S, 1.5S, and 95TA.

[d] Permissible tin range, 4.5 to 5.5 percent.

[e] Permissible tin range, 1.5 to 2.5 percent.

[f] Tin maximum, 0.25 percent.

[g] Permissible tin range, 0.75 to 1.25 percent.

(NOTE: Solder Metal Specification ASTM B—32 is printed in full in the *1975 Annual Book of Standards Part 8*, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103).

TABLE 6—Solder Compositions (as listed in ASTM B-32-70, Table 1)

Composition	Tin	Lead	Antimony,	Bismuth max	Silver max	Copper, max	Iron, max	Zinc, max	Aluminum, max	Arsenic, max	Cadmium, max	Total of all others, max	Approximate melting range[1] Solidus	Liquidus
	%	%	%	%	%	%	%	%	%	%	%	%	°C (°F)	°C (°F)
Sn96	Remainder	0.10, max	. . .	. . .	3.6 to 4.4	0.20	. . .	0.005	. . .	0.05	0.005	. . .	221 (430)	221 (430)
Sn70	69.5 to 71.5	Remainder	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.03	0.001	0.08	183 (361)	193 (379)
Sn63	62.5 to 63.5	Remainder	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.03	0.001	0.08	183 (361)	183 (361)
Sn62	61.5 to 62.5	Remainder	0.20 to 0.50	0.25	1.75 to 2.25	0.08	0.02	0.005	0.005	0.03	0.001	0.08	179 (354)	179 (354)
Sn60	59.5 to 61.5	Remainder	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.03	0.001	0.08	183 (361)	191 (376)
Sn50	49.5 to 51.5	Remainder	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.025	0.001	0.08	183 (361)	216 (421)
Sn40	39.5 to 41.5	Remainder	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	183 (361)	238 (460)
Sn35	34.5 to 36.5	Remainder	1.6 to 2.0	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	185 (365)	243 (469)
Sn30	29.5 to 31.5	Remainder	1.4 to 1.8	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	185 (365)	250 (482)
Sn20	19.5 to 21.5	Remainder	0.80 to 1.2	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	184 (363)	270 (518)
Sn10	9.0 to 11.0	Remainder	0.20, max	0.03	1.7 to 2.4	0.08	. . .	0.005	0.005	0.02	0.001	0.10	268 (514)	290 (554)
Sn5	4.5 to 5.5	Remainder	0.50, max	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	308 (586)	312 (594)
Sb5	94.0, min	0.20, max	4.0 to 6.0	. . .	0.015	0.08	0.08	0.03	0.03	0.05	0.03	0.03	235 (455)	240 (464)
Pb80	Remainder	78.5 to 80.5	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	183 (361)	277 (531)
Pb70	Remainder	68.5 to 70.5	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	183 (361)	254 (489)
Pb65	Remainder	63.5 to 65.5	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	183 (361)	246 (475)
Ag1.5	0.75 to 1.25	Remainder	0.40, max	0.25	1.3 to 1.7	0.30	0.02	0.005	0.005	0.02	0.001	0.08	309 (588)	309 (588)
Ag2.5	0.25, max	Remainder	0.40, max	0.25	2.3 to 2.7	0.30	0.02	0.005	0.005	0.02	0.001	0.03	304 (579)	304 (579)
Ag5.5	0.25 max	Remainder	0.40, max	0.25	5.0 to 6.0	0.30	0.002	0.005	0.005	0.02	0.001	0.03	304 (579)	380 (716)

[1]For information only.

TABLE 7—Alloy Compositions From Federal Specifications QQS-571

Prepared and distributed under the auspices of the Solder Manufacturers Committee of the Lead Industries Association, Inc.

While every effort has been made to assure that the information given in this booklet is technically correct, neither the Lead Industries Association nor the Solder Manufacturers Committee warrant its accuracy.

Excerpts reprinted from AWS Soldering Manual, First Edition, by permission of the American Welding Society.

LEAD INDUSTRIES ASSOCIATION, INC.
292 Madison Avenue, New York, N.Y. 10017

10/78/15

PRINTED IN U.S.A.