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MATERIALS FOR SOLDERING and SOLDERING PROCESSES

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1. Basic Parameters for Soldering

a) To provide an electrically conductive path (e.g., electronics)
b) To connect components together mechanically (e.g., tinplate cans).
c) To allow heat to flow from oen component to another (e.g., heat exchangers).
d) To retain adequate strength at temperatures from cryogenic levels to well above that of boiling water (e.g., freezing plant, automobile radiators.
e) To form a liquid-or gas-tight seal (e.g., reaction vessels).

Soft-soldering is the joining together of two metals using a low melting temperature alloy as the filler metal. The melting temperature of the solder alloy is very much lower than the melting point of the basis metals being joined. The filler metal wets and alloys with the basis metals and then, by capillary action, is drawn into and fills the gap between them, thus forming a metallurgical bond between the components of the joint.

Solders act by wetting the basis metal surfaces forming the joint. In order that the wetting and subsequent metallurgical bonding may occur, the surfaces to be joined must be perfectly clean. This necessitates the use of a flux. The wetting action must usually occur quickly for a soldering process to be viable from the production standpoint.

Wetting results in reaction between solder and substrate which usually results in the presence, at the interface, of layers of intermetallic compounds. The amount and speed of wetting and spreading of solder which occurs, generally referred to as solderability, depends on the free energies of the various surfaces involved in the soldering system.

Any surface contamination which affects surface energies, influences wetting and compound formation. In the extreme case "dewetting" of solder occurs, perhaps after an initial wetted state existed.

The basic variables in a soldered joint are :

SUBSTRATE METAL (S)
SOLDER ALLOY
FLUX
HEAT INPUT

The production of a soldered joint can be divided into a number of basic steps :

i) The metal parts to be joined are shaped so that they fit together.
ii) Their joining surfaces are specially claned, or else prepared by precoating.
iii) Soldering flux is applied (the parts may sometimes be assembled at this stage).
iv) Heat and molten solder are applied and the solder usually distributes itself between the joint surfaces by capillary attraction.
v) The joint is cooled.
vi) Flux residues are removed, as required.

Each of these has to be correctly selected and controlled to achieve economically, soldered joints of high integrity.

2. Solder alloys

The characteristic of soft solders is that they all have a low melting point; each alloy in significant commerical usage has a liquidus temperature below the melting point of pure lead (327° C). The bulk of commonly used solders melt below about 250° C.

The majority of solders used are based on the binary system of tin and lead. Other alloys are based on tin and antimony, tin and silver, and the ternary lead-tin-silver system. There are a few other special solders which are also employed in specific applications.

In tonnage terms, nearly all of the solder used in electronics is 60-63% tin-balance lead.

Solder is manufactured in many different forms to meet the needs of particular applications. In many cases, flux and solder are combined in one product, for example in flux-cored solder wire or in solder pastes. For the baths of dip-, drag- or wave-soldering machines, ingots of many convenient sizes are produced. Reels of solder as wire are supplied in a range of diameters from about 0.7 mm to over 5 mm.

Cored solder contains one or more strands of paste flux within the wire. The flux to solder ratio by weight is variable according to requirements. Solder preforms made from foil are available in a variety of shapes and sizes as rings, washers, discs, collars, tubes and many other shapes.

Solder paints, creams and pastes are basically thixotropic suspensions of solder powder in a liquid or semi-liquid flux and can be dispensed automatically from machines.

It is recommended that soldered joints are used in such a manner that, if they are subjected to a load, it is transmitted to the film of solder in the joint as a shear stress.

In many applications high service temperatures are experienced, as well as stressing of the joint. Creep resistance is then important and where vibration or thermal fluctuations occur, fatigue resistance is also important. Many of the data obtained under comparable conditions of test are now available for a variety of solders.

Certain impurity elements, when present in sufficient quantities, may affect the wetting properties of solder. Some elements when present in excess of their solubility form intermetallic compounds. Other elements may cause increased drossing of the solder. These effects could be of particular importance in the high-speed soldering processes used in the electronics industry.

3. Fluxes

Soldering fluxes are capable of promoting or accelerating the wetting of metals by solder.

A flux :

a) should exclude air up to soldering temperature,
b) should dissolve any oxides on the metal surface or on the solder,
c) should be readily displaced from the metal by the fluid solder,
d) should be removable after soldering

Compositions range from resins of low reactivity to much more corrosive acids and acidic inorganic halides. The production specification or contract may stipulate the type of flux to be used. For easiest soldering the strongest flux allowable is preferred.

Recent National Standards have incorporated a larger number of categories, in order to indicate the chemical nature of basis of each category. These Specifications usually include performance requirements for each category.

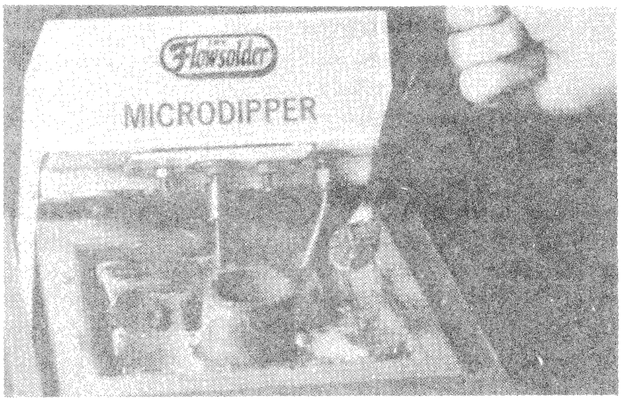
Flux may be in liquid form with various solvents, or as a paste on its own, or incorporated into cored solder wire or into solder preforms. It is important to apply the correct quantity of flux before soldering.

Ease of removal of flux residues is usually an important requirement for electronics assemblies.

4. Components and surfaces

Since the solderabiliry of different metals varies, the preparative procedures and the soldering flux are selected to suit each particular alloy. However, certain metals which have very tenacious oxide films and are relatively "unreactive" are generally not soldered. The more commonly used materials can be made easier to solder by coating them with a suitable metal, such as tin.

Tin, cadmium and gold are easily wetted without any form of pre-cleaning and with the use of a weak flux. Silver forms sulphide films which reduce solderability. Copper, brass, bronze and steels all oxidise to some extent when exposed to the atmosphere. The necessity for pre-cleaning depends on the extent of oxidation and the activity of the flux.



Materials which are not solderable by normal techniques need to be electroplated with a more easily soldered metal such as copper or nickel. Ceramics are included in this category.

Specification of the correct finish on the components will afford a guarantee of reliability of the soldered joints in the completed assembly. Surfaces should be chemically clean at the time of soldering; this also applies to the preparation of basis metals to be precoated as an aid to soldering. Materials which have been satisfactorily electroplated with a coating may give trouble when soldered if the preparation prior to plating is inadequate.

The conductive tracks on printed circuit boards and many component terminations are made of copper which, although solderable when fresh, will become less so when exposed to the atmosphere. By protecting these surfaces with a selected metallic coating, these limitations can be avoided and a solderable surface presented to the solder during soldering.

Metal coatings can be broadly classified in three groups- "fusible", "soluble" and "insoluble". A fusible coating becomes molten at the soldering temperature and is washed off during soldering. Soluble coatings react with, or dissolve in, molten solder rather rapidly so the solder may eventually be in contact with the basis metal. Insoluble coatings dissolve slowly and are often used as an intermediate coating on basis metals which are impossible to solder.

Tin and 60% tin-40% lead coatings comprise those in the "fusible" category and are excellent for providing and maintaining solderability. Provided that their thickness is at least 5μm, any oxide film on the surface is disrupted, allowing solder to wet the underlying surface. Thin coatings suffer from porosity, allowing corrosion. Intermetallic compound formation at the coating/substrate interface will also tend to lower solderability of thin coatings.

Electroplating probably is the most commonly used way of applying a coating and both matt and bright tin and tin-lead coatings are in use. Bright tin has organic additives which may affect solderability. Matt coatings can be brightened by momentary melting (reflowing) which ensures wetting of the substrate.

A copper or nickel undercoat must be used on basis metals containing zinc, such as brass, because zinc will diffuse rapidly through a tin or tin-lead coating and by atmospheric reaction result in zinc-rich surface films, which impair solderability.

The solderability of most gold electrodeposits is good. However, problems can arise when soldering to thick gold, especially when hand soldering.

Fromation of a hard, brittle intermetallic compound, $AuSn_4$, gives rise to a low strength when soldering coatings greater than about 1.5μm thick.

Non-metallic coatings are usually rosin lacquers which are displaced in contact with the solder. "Self-fluxing" coatings on copper wire may be removed by mechanical abrasion or by immersion in solder at 400°C.

Solders are weak compared with the metals they are used to join. Thus, the joint must be designed to avoid undue dependence upon the strength of the solder. There are instances where solder is solely a sealing metal. Lap joints offer joints with maximum strength. One way of imparting strength to a joint is to shape the suraces so that they engage or interlock mechanically and to use the solder for sealing and rigidising the assembly, e.g. a lock-seam joint, rivets, spot-welding.

In electronic assemblies, many joints are simple non-capillary fillets of solder on circuit boards. Greater strength is obtainable where terminations are soldered into plated-through holes. The design of printed circuit boards is important and must be carefully specified.

5. Ancillary materials

5.1 Flux residue slovents

It is essential to wash soldered assemblies carrying inorganic halide residues first in dilute acid to avoid hydrolysing them. Water washing should follow. Agitation and use of brushes may also aid flux removal.

Organic acid type aqueous fluxes used in wave soldering printed circuit assemblies are removed in warm water containing wetting agent.

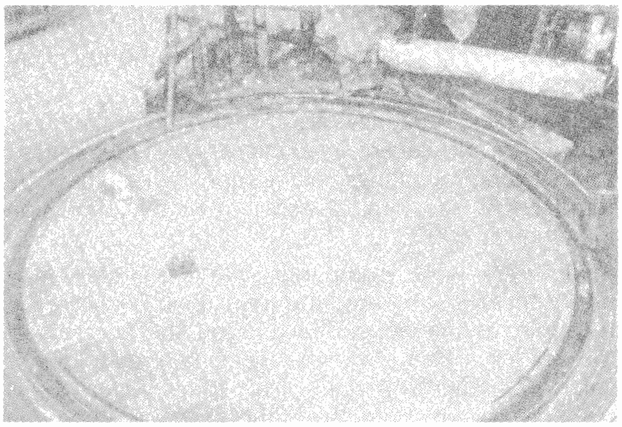
To remove residues of rosin fluxes, contact with hot organic solvent is usual. The use of aqueous detergent cleaning to remove residues, or a water-solvent mix is also practised.

5.2 Solder masks

Often in dip- or mass-soldering, areas must be masked to prevent wetting by the solder. In printed circuit boards "resist" may be screen-printed to restrict solder to each joint area. These are usually curable lacquers.

5.3 Conformal coatings

Thick coatings of, for example, epoxy rosin or elastomer may be applied to print circuit assemblies to totally exclude the atmosphere. Such hard, rigid coatings may apply undue stress to soldered joints unless care is taken. Fluxible protective coatings are preferred.



6 Soldering irons

The most common method for soldering is the soldering iron. The bit of the iron stores heat and conveys it to the work. It may store and deliver molten solder and flux. It is **essential** that the bit surface is wetted by the solder ("tinned"). Size and shape of the bit are determined by the amount of heat that has to be supplied. The wattage is related to the rate of working. The size and shape may be varied to suit the joint size and configuration. For many types of work thermostatically controlled irons are preferable.

Soldering bits are usually made of copper, protected by thick coatings of iron or nickel and are generally decribed as "long-life" bits. The soldering bit is held on the workpieces to heat them and solder is applied to the work close to the bit. The condition of the bits should be checked regularly.

7. Other manual processes

Gas flames or gas/air torches are used for large sheet metal assemblies etc. It is relatively simple to use flame heating methods in a mechanised soldering system.

In resistance soldering, the work is connected to one terminal of a low-voltage transformer whilst a carbon rod is connected to the other terminal at the point of contact of the carbon with the workpiece. Local heating occurs by contact resistance; the carbon electrode is cold and is not wetted by the solder.

In the technique of resistance "reflow soldering", two electrodes are applied, one on each side of the area requiring heating. It is usual to employ thick coatings of solder on the surfaces to be joined so that no extra solder need be added. Sophisticated equipment is available which controls heating time.

In radio-frequency induction soldering, the workpiece is the secondary of a transformer converting electrical energy into heat using eddy currents. No contact with an external heat source is necessary. The technique is relatively expensive in terms of capital equipment costs; correct design of induction coil is vital. The rate of heating is pre-set by a power control. Solder washers or preforms are assembled with the components being joined and it is essential that surfaces have a high solderability.

In optical/laser soldering, a beam focusses on a small area, which means high heating rates may be achieved. Because of the high rate, close control over the parameters is essential.

In hot gas soldering, a fine jet of gas heated to above the liquidus temperature of the solder is directed at a solder preform positioned where required. The gas acts as a heat transfer medium, but it acts also to exclude access of air.

8. Mechanised soldering

Mechanised soldering is defined to include processes in which machinery takes over the manual operations in soldering.

In wave soldering, solder is pumped out of a narrow slot to create a standing wave in the solder. The printed circuit board, after fluxing and drying, is conveyed across the crest of the solder wave by a conveyer system which follows a straight line path. Different wave configurations are chosen for different applications. SMD loaded boards usually require two successive different wave types.

Some machines incorporate jets after the wave to reduce solder pick-up.

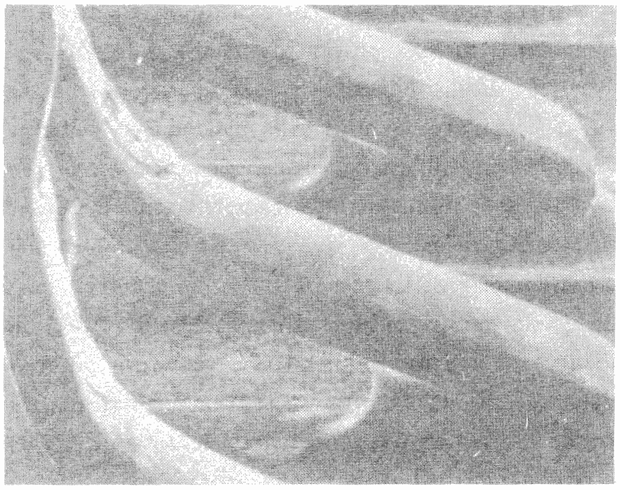
Many commercial makes of wave-soldering machine are available, from small bench-top units to very large, high production capacity machines. The choice should be part of the initial planning of the production scheme.

In wave-soldering methods, it is usual for there to be successive operations of circuit loading, flux application, flux drying, soldering, cooling, flux removal and finally off-loading. Surfaces having good solderability are vital.

In another technique, components are inserted into boards without cutting the leads, the assembly is soldered, using a deep wave, the exposed leads are cut by passage over slitting wheels and the assembly is re-soldered over a normal wave (solder-cut-solder system).

In drag soldering, a conveyor system is used to move the board so that it passes over a fluxing and flux-drying stage, and then enters a long solder bath and travels horizontally along the solder surface before being withdrawn. Control systems can vary the speed of travel and there are facilities for increasing the contact with the solder by a dwell period.

Vapour-phase soldering makes use of the latent heat liberated when a hot organic vapour condenses on the cold assembly and may be a conveyorised or batch process. Versatility is limited slightly by the boiling-point of the organic fluids available. Reflow soldering using an infra-red heat source in a conveyor oven is also widely practised.



9. Final cleaning

Occasionally, residues of rosin-basis fluxes may be allowed to remain on circuit boards, but this interferes with electrical function testing using a "bed of nails".

Rosin fluxes are removed by mechanised organic solvent or aqueous detergent systems. Organic aqueous fluxes are removed by water-based cleaning solvents.

Compatibility of components, and marking, with the solvents must be checked. "Open" components cannot be passed through cleaners. ■