FINAL REPORT

on

INVESTIGATION OF INDUSTRIAL USES OF TIN-FREE AND LOW-TIN SOLDER: PART III

by

C.A. REICHELDERFER AND B.W. GONSER
BATELLE MEMORIAL INSTITUTE

WAR METALLURGY COMMITTEE

of

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL

Advisory to

NATIONAL DEFENSE RESEARCH COMMITTEE
of
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

and

OFFICE OF PRODUCTION RESEARCH AND DEVELOPMENT
of
WAR PRODUCTION BOARD

Serial No. W-126

Copy No. 64

July 12, 1944

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL

WAR METALLURGY COMMITTEE
2101 CONSTITUTION AVENUE, WASHINGTON 25. D. C.

September 4, 1945

Mr. Ralph H. Phelps,
Assistant to Director
Engineering Societies Library
29 West 39th Street
New York 18, New York

Dear Mr. Phelps:

This is in reply to your letter of August 28th making inquiry as to whether the reports preceding W-126 were progress or final reports.. Both are final reports. Parts I and II respectively. One is classified "Confidential", the other "Restricted" and neither one has been released for publication.

Part III which is released and of which you have a copy, is the only one of the three that deals in general with the uses of tin free and low-tin solder. The two remaining classified portions of the final report deal only with specific industries and limited uses.

Very truly yours;

Helen Purdum

Helen Purdum, Librarian
Research Information Division
War Metallurgy Committee,

HP:nd

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NATIONAL ACADEMY OF SCIENCES
2101 Constitution Avenue
Washington 25, D. C.

July 12, 1944

Dr. C. K. Leith, Chief
Metals and Minerals Branch
Office of Production Research and Development
War Production Board
Washington 25, D. C.

Dear Dr. Leith:

Attached is War Metallurgy Committee Research Report, Serial No, W-126, "Investigation of Industrial Uses of Tin-Free and Low Tin Solder: Part III".

This is a final report on the work done under Research Contract WPB-20 between the War Production Board and Battelle Memorial Institute,. This contract has been supervised and directed by the War Metallurgy Committee, under the provision of Contract WPB-1 between the War Production Board and the National Academy of Sciences.

Yours sincerely,

(signed) Frank B. Jewett,

Frank B. Jewett,
President

Enclosure

NATIONAL ACADEMY OF SCIENCES

NATIONAL RESEARCH COUNCIL

WAR METALLURGY COMMITTEE

2101 CONSTITUTION AVENUE, WASHINGTON 25, D. C.

July 3, 1944

MEMORANDUM

To: Dr. Frank B. Jewett, President, National. Academy of Sciences

From: The War Metallurgy Committee

Subject: Research Report No. W-126 to the War Production Board

Final Report on Investigation of Industrial Uses of Tin-Free and Low-Tin Solder: Part III

The attached final report has been submitted by B.W. Gonser. of Battelle Memorial Institute under their Contract WPB-20 with the War Production Board.

Acceptance as a satisfactory final report on the work done under that contract is recommended,

Respectfully submitted,

Louis Jordan, Executive Secretary
War Metallurgy Committee

Enclosure

R.H. Phelps

PREFACE

This report is pertinent to the project designated by the War Metallurgy Committee as WPB Research Project NRC-542.

The distribution of this report is as follows:

copy No. 1 - Dr. C. K. Leith, Chief, Metals and Minerals Branch, Office of Production Research and Development,' War Production Board
Copy No. 2 - Dr. Frank B. Jewett, President, National Academy of Sciences
Copy No. 3 - Clyde Williams, Chairman, War Metallurgy Committee
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Copies No. 7 thru 21 - Transmitted to Dr. C. K. Leith, Office of Production Research and Development, War Production Board, for distribution
Copy No. 22 - B. W. Gonser, Investigator, WPB Research Project NRC-542

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Battelle Institute.
Columbus 1, Ohio.
June 29, 1944

Mr. Clyde Williams, Chairman
War Metallurgy Committee
2101 Constitution Avenue
Washington 25, D. C.

Dear Mr. Williams:

The attached report covers a general resume of information on soldering with low tin and tin free solders. It has been prepared particularly for use by the Tin-Lead Branch of the War Production, Board at the request of Mr. Vogelsang;

An attempt has been made in this report to give useful information to metallurgists and plant managers who are interested in using low tin and tin free solders, and those who have had difficulty in converting to such solders. No attempt has been made to give detailed information on soldering technique,. since this phase of soldering is well covered by several articles which have been included in the list of references.

Your very truly,

(signed) Bruce W. Gonser

Bruce W. Gonser

BWG:mj

FINAL REPORT

on

WPB RESEARCH PROJECT NRC-542; WPB-20

INVESTIGATION OF INDUSTRIAL USES OF LOW-TIN AND TIN-FREE SOLDER

From September 20, 1943, to March 20, 1944

From:
Battelle Memorial Institute
505 King Avenue
Columbus 1, Ohio

Report Prepared by;
Charles A. Reichelderfer
Bruce W. Gonser

ABSTRACT

The successful transition from normal soft solders to those low in tin or tin-free has been largely possible through changes in soldering technique. Higher temperature, necessary with the substitute solders, has favored use of a torch, electric resistance, induction, or furnace soldering methods in place of a soldering bit. Greater precautions in preparing the work for soldering has been necessary, Stronger fluxes, particularly the use of fused salt fluxes have frequently made the use of tin-free or low-tin solders possible. In this report the preparation of work, application of heat, and available solders and fluxes have been discussed to give a better background of fundamental requirement for saving tin in solders.

A few examples of the use of substitute solders in industry have been given following recent survey, in order to indicate where they may be or may not be successfully applied.

No attempt has been made to give the operating details of soldering, but several recent articles on the technique of soldering are given as references. General precautions in going, to substitute solders have been noted and the need has been stressed for more than a superficial trial of a new solder and for discussion of, soldering problems with those who are now successfully using solders with less tin.

FINAL REPORT

on

WPB RESEARCH PROJECT NRC-542, WPB-20

INVESTIGATION INDUSTRIAL USES OF LOW-TIN AND TIN-FREE SOLDER

From September 26, 1943, to March 20, 1944

From:
Batelle Memorial Institute
505 King Avenue
Columbus 1, Ohio.

Report Prepared by:
Charles A. Reichelderfer
Bruce W. Gonser

INTRODUCTION

Solders have been used in the joining of metals since the early days of the Romans and perhaps even previous to that time. At no time was the use of solder more extensive than now, when the demand for implements both of peace and of war is greater than ever before. Meeting this increased demand has been made even more difficult by the loss to the United Nations of the major tin producing fields necessitating the conservation of tin in every way possible.

Since the most acceptable substitutes for tin-lead solders, particularly those containing cadmium have been on the scarce or critical list, the development and use of low tin solders and lead-base solders containing no tin was necessary. To some extent, the change in properties caused-by the low tin contents has been offset by additions of minor amounts of antimony, bismuth, arsenic, and silver; but changes in soldering technique have been far more effective in compensating for the lower tin content.

SOLDERS

Before World War II, soft solders in this country were of rather simple composition, consisting mainly of lead and tin with occasional additions of antimony in amounts of 2% or less. Cadmium-base solders and tin-antimony solders were used for special applications Since the start of the war, however, many variations have come into the spotlight.

Present low-tin solders generally have higher melting points and longer freezing ranges, requiring a different technique in use than with the high tin-lead solders. Whereas, for example, a 50-50 tin-lead solder is completely melted at 421°F. and has a. freezing range of 50°F. , a 20% tin solder containing. one percent of. antimony and 0.5 percent of silver is not completely melted until 511°F. and has a freezing range of 155°F. This means that a higher temperature is necessary in the use of the latter solder and the joint must be held rigid through a longer period. Although a higher temperature is required; it is just as important not to overheat;- hence, closer control is needed.

The composistions and melting ranges of some of the more common solders are given in Table 1; Emergency specifications of the A.S.T.M. covering this general field are given in Table 4 of the Supplement. Just as the normal tin-lead solders have different properties suiting them for various applications, so also do the low-tin and tin-free emergency solders have specific properties that fit them for particular uses.

TABLE 1. COMPOSITION AND FREEZING RANGE OF SOME TIN-LEAD AND MODIFIED LEAD-BASE SOLDERS

Tin	Lead	Antimony	Silver	Copper	Temperature, °F. Solidus	Liquidus	Freezing Range
15	85				437	543	106
20	80				361	523	162
30	70				361	486	125
40	60				361	453	92
50	50				361	421	60
60	40				361	372	11
63	37				361	361	0
			Modified Solders*				
-	99	-	1	-	579	604	25
-	97.25	-	2.5	0.25	576	590	14
-	97.5	-	2.5	-	579	579	0
2.25	95.25	2.0	0.25	-	457	577	120
5	94	-	1.00	-	561	572	11
19	80	1.0	-	-	365	523	158
20	79.58	-	0.42	-	352	523	171
20	79.25	-	0.75	-	351	523	172
20	78.5	-	1.5	-	350	517	167
20	78.57	1.0	0.43	-	356	511	155
20	77.50	2.0	0.5	-	363	505	142
20	77.25	1.5	1.25	-	354	504	150

*D. L. Colwell and W. C. Lang, Conservation of Tin in Soft Solders, Preprint 35 A.S.T.M., 1943.

Lead-Silver Solders

The greatest conservation of tin in solders can be made, of course, by eliminating the tin entirely. Lead alone is being used successfully in coating steel parts by hot dipping(1) after thorogh cleaning and fluxing; but, with the exception of a very few applications, it does not have the requisite wetting tendency, flowability, or strength for a successful solder. By adding a little silver, however, solderability is markedly

(1) W. Yonkman: New Lead Coating Process Eliminates Use of Zinc Alloy. Product Engineering, May 1943, pp. 282-283.

increased and the melting range is lowered somewhat. This forms the basis for a series of tin-free solders which has gained wide usage.

A 2.5% silver addition gives the eutectic or lowest melting point of this group. This composition is much used for general soldering. Addition of 0.25% copper is optional. It is thought to give better wetting, a slightly stronger joint, and higher creep resistance in electrical work,. The silver content is sometimes raised to 5% for greater assurance of solderability, but for the sake of economy the tendency has been to drop the silver to 2% or even 1%, if tests showed such change to produce the desired properties of the joint.

Probably the most important commercial substitution of silver-lead for high tin-lead solder has been in the soldering of side seams on tin cans, although recently the trend has been to reduce the silver content to only a percent or so, or eliminate it entirely and depend upon a very low tin-lead solder for this application. Since small amount of tin is picked up by the action of the solder bath on the tin plate container, a composition of about 2% silver, 3 to 5% tin, balance lead, is soon established in the bath when starting with a plain 2-2.5% silver-lead solder. The tin gives improved resistance to tarnishing. In fact, addition of only one percent of tin improves the brightness of the soldered joint. With higher than 5 or 6% tin content the effect of tin on the melting range becomes marked, and "hot breaks" or fractures in the joint may occur from cooling strains while the solder is not entirely solidified The aid silver has given to the solderability of lead has encouraged the addition of small amounts to 20% tin-lead solders, as shown in Table 1, but there is some divergence of opinion concerning the advantage of silver with tin contents of 20% or more.

In general the silver-lead solders are fitted for applications where a relatively high temperature of application is not a serious handi--cap, and where strong acid fluxes can be used. With tinned surfaces, non-corrosive fluxes can be used. The short freezing range is an advantage in many applications. The silver-lead solders as a class are slightly stronger particularly at elevated temperatures, than tin-lead solders.

Resistance of this solder to outdoor weathering and underground corrosion not been fully determined as yet. Excessive formation of basic lead carbonate at the joint has been reported (1) in one instance where solder-coated steel covers were soldered to antimonial-lead cases. In another application where lead parts were joined to lead, complete disintegration of the solder occurred within two years (1). Caution, therefore, should be observed in using this solder for permanent installation under-ground or when fully exposed to outdoor corrosion. Addition of a few per cent of tin should be helpful in retarding corrosion found by the can manufacturers.

Antimony Additions

(Copy provided by library came with this piece missing)

Antimony has frequently been added to tin-

for increased strength and for economy. One per cen

ered to replace two percent tin, but there is a limit to the extent of such substitution. About six per cent antimony is soluable in tin hence, antimony to the extent of six per cent of the tin content remains in solu-tion and gives no particular trouble. Above this amount, crystals of a high-melting antimony-tin compounds are formed, which not only embrittles the solder, but makes it sluggish and rough. Small amounts of antimony

(1) Western Electric Company.

with or without silver additions are consequently used in some of the modified solders shown in Table 1, to lower the melting range, give a stronger solder, and aid resistance to creep or slow movement under continued pressure.

The addition of antimony is definitely harmful when soldering zinc or galvinized parts and Nightingale [1] has found antimony deleterious in low tin solders for use in soldering steel because of deteriorating joint strength. Experience in the soldering of steel in this country does not substanciate this latter contention, however, since additions of up to 5% frequently have been found advantageous. For example, the joint strength of a 5% tin-5% antimony solder has been found to be fully equal to that of a plain 10% tin-lead solder.[2] Antimony is a particularly useful addition where increased resistance to creep at room for elevated temperature is needed.

A lead-base high-antimony solder containing 0 to 5% tin and 4 to 8% antimony has been suggested.[2][3] At first this high antimony content seems excessive since in high tin solders an effort has always been made to keep a low ratio between antimony and tin, but since the tin content is low (well within the solid solution, limits), it is probable that objection- [redacted]-tin compound crystals would not form. This solder has been [redacted]lly in several applications.

Bismuth-Containing Alloys

Bismuth greatly lowers the melting range of tin-lead solders and was a natural selection when additions for substitute solders were first suggested. The high bismuth-containing solders are used for special applications where a low melting point is essential and where the increased.

(1) S. J. Nightingale and O. F. Hudson: Tin Solders, Second Edition. British Nonferrous Metals Research Association, London, 1942, p. 73.
(2) Private communication from A. J. Phillips, American Smelting and Refining Company.
(3) W. R. Lewis: Tin and Antimony in Lead Alloys. Tin and Its Uses. March 1944, pp. 13-14

cost or poor availability is not too important. Such high bismuth alloys expand during and after solidification, which can be a disadvantage in some joints and an advantage in giving a tighter fit in others. Since the temperature of soldering is so low for these alloys, there is much less alloying, and fluxing is more difficult. The strength of joints made with these solders, consequently, is apt to be low. In general, bismuth in a solder is like lead and, except for lowering the melting point, is more a substitute for lead than for tin.

TABLE 2. HIGH BISMUTH SOLDERS

Composition, %			Melting Range, °F.	
Bismuth	Tin	Lead		
67	17	16	300-203	
56	22	22	220-203	
52.5	15.5	32	203	(eutectic)
33.3	33.3	33.4	290-403	
14	43	43	325-290	

In some applications, the use of intermediate bismuth solders with low tin has been satisfactory. The long solidification range of the low tin solders, which may be amplified in this case by producing a small amount of a very low melting ternary eutectic, gives a weak joint or, one that is "hot short" throughout a large portion of the cooling time. Frequently the increased cost and care needed to prevent strain during the cooling period do not compensate for the lowered soldering temperature. Scarcity of bismuth is also a factor. Additions of up to 1% are frequently and advantageously made, however, because of their effect in lowering the soldering temperature.

Miscellaneous Solders

Some of the cadmium-containing solders are excellent, but must be disregarded because of the need for using cadmium in other applications. A 90% lead, 8% cadmium 2% zinc-alloy is probably the most promising substitute because of the relatively small amount of cadmium used. It is particularly useful in soldering zinc and galvanized parts. The melting range of about 410-530°F. is but slightly more than the melting range for low tin-lead solders.

Indium has been said (1) to give improved solderability to silver-lead solders when added in amounts of 1 or 2%. The high cost of indium has discouraged its use.

PREPARATION OF WORK

The formation of a good joint by soldering depends fundamentally on the wetting of the surfaces to be joined by the soldering alloy. Most metals are wet only with difficulty by lead, but are wet easily by tin. High-tin alloys, therefore, have been preferred for ease of wetting. With careful preparation and attention to soldering technique, however, satisfactory joints also can be obtained with low-tin alloys in most cases.

Metals to be soldered must be clean and free from scale. Dirt, grease, oxide, and other foreign material must be removed either mechanically or chemically. Files, scrapers, emery paper, steel wool, sand blasting, or other, mechanical means can be used. Commercial solvents and pickle liquors at times are more economical and more efficient than mechanical methods.

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(1) Indium News, Volume 1, No. 1, Indium Corporation of America, 1942.

Tin Plate and Tin-Coated Metals.

Tin, because of its resistance to oxidation in the atmosphere and the ease with which it alloys with lead, is one of the easiest metals to wet with tin-lead solders. Tin plate and tin-coated metals can be joined readily by soldering, and little, if any, preparation is needed other than fluxing. For this reason, metals to be soldered are frequently tinned.

Tin plate is usually coated with a film of palm oil, which not only protects the surface, keeping the metal bright but also has fluxing properties that aid in soldering. Occasionally, however, oil, lacquer, or other materials which seriously interfere with soldering are used on tin plate. Almost any of the commercial solvents such as trichloroethylene, benzene, carbon tetrachloride etc., will serve to remove these coatings, leaving a clean surface for soldering.

Copper and Copper Alloys

Copper when clean is also easily soldered, and is frequently applied by electroplating or displacement coating to prepare other metals for soldering. Oxidized copper on the other hand, is difficult to solder and must be cleaned. Mechanical cleaning can be used, but often pickling is more practical. Immersion for 5 to 15 minutes in 10 to 15% sulphuric acid at about 150°F. followed by a water rinse is usually sufficient for copper and such copper-base alloys as bronzes and brasses. A 10 to 15% nitric acid solution is also frequently used, especially when trouble is encountered in soldering after the sulphuric acid pickle.

Iron. Steel, and Galvanized Iron

Black plate, cast iron, galvanized iron, and other steel parts are much more difficult to solder than copper and tin and require more careful preparation. Again, abrasion will often produce a clean, solderable surface. Ordinary steels can be cleaned from oxide and scale by pickling in 0.5 to 15 per cent sulphuric or muriatic acid at 150° F. Tinning previous to soldering is the solution to some difficult soldering problems.

Cast iron, because of flake graphite and silicon, requires special preparation. Mechanical means of removing the casting skin. by shot blasting, grinding, filing, etc., usually are insufficient preparation because of the graphite present. Coating such cleaned parts with pure iron, or with a relatively heavy coating of copper by electrodeposition, is effective, but requires considerable time, equipment, and specialized attention. A more practical. method is to remove the surface graphite by dipping the parts to be joined in a hot molten bath of equal parts sodium nitrate and potassium nitrate. This must be followed by washing and by a brief pickling treatment, as in a cold 5 per cent hydrofluoric acid solution, however, to remove the oxidized film produced. Alternately; a second fused salt bath may be used.(1) A proprietary flux(2) is also satisfactory for, this second treatment.

(1) Kolene Corporation, 315 Boulevard Bldg.; Detroit, Michigan.
(2) "D-W" flux, National Lead Company, 111 Broadway, New York City.

Clean galvanized iron and zinc need no preparation, but can be soldered by using an active flux such as zinc chloride-ammonium chloride preferably containing free hydrochloric acid. Dirty or oxidized zinc, however, should be cleaned with a solution of hydrochloric acid and washed with water before an attempt is made to apply solder.

General

As with tin plate, copper and steel, other metals can be prepared for soldering by removing surface films mechanically by degreasing and suitable pickling. Thus stainless steel and high-chromium steels are best cleaned with hydrochloric acid. Lead and lead alloy are readily scraped clean. Malleable iron may be treated like cast iron if simpler cleaning operations are ineffective. Nickel and its alloys may be best cleaned with nitric acid.

FLUXES

It is not sufficient merely to clean a surface to be soldered, for that surface must be kept clean and free from oxide until it is coated with the solder. All common metals on contact with air form a thin oxide film which, if not removed, would prevent the perfect metal-to-metal contact needed-for adhesion or alloying. This oxide coating must be removed and precautions taken to prevent its reforming. Fluxes, therefore, must perform two operations: (1) remove light oxide films, and (2) prevent them from reforming until the solder has come into intimate contact with the base metal.

In addition to these two requirements, fluxes must (1) have a melting point below that of the solder so that inclusions will not be entrapped in the solder or between the solder and the surface being soldered; (2) be capable of withstanding the heat, without breaking down at soldering temperatures or evaporating too rapidly, charring, or decomposing to leave a residue; and (3) aid the solder in wetting and flowing over. the surface, and cover the surface until completely displaced by the solder,

A number of substances possess these properties in varying degrees. They may be divided into two groups, corrosive and relatively noncorrosive. Since tin-free and low-tin solders are higher melting and alloy more slowly than those of prewar type, stronger fluxes or better preparation of the joints are usually necessary. When acid fluxes or fused salt baths can be used, there has been much less difficulty in changing to low-tin solders.

Corrosive or Acid Fluxes

Most of the corrosive or acid fluxes contain zinc chloride. The one -most commonly. used for ordinary work. is normally prepared by the plumber or tinsmith by adding an excess of zinc to hydrochloric (muriactic) acid. Because of the unpleasant and irritating fumes and the unpredictable strength of flux prepared in this manner, it is preferable to dissolve an ounce of zinc chloride in the form of flakes or sticks in four ounces of water. This is an active and efficient flux which on application to the work being heated evaporates leaving a deposit of fine crystals of zinc chloride. As these crystals melt, oxide films are dissolved and the work is protected from further oxidation: However, since the melting point of these crystals is 500°F,(262° C.)and the final solidifying temperature of solders containing over 20 per cent of tin is. 361°F. (183°C.) flux particles are apt to be entrapped, preventing the solder from adhering to the base metal and thus weakening the joint.

Ammonium chloride (sal ammoniac) added to zinc chloride in the ratio of one part of ammonium chloride to three parts of zinc chloride forms a low-melting eutectic that is molten above 356°F.(180°C.), Better results are obtained, however, by using nine parts of zinc chloride to one part of ammonium chloride. The eutectic formed.by mixing nine parts of zinc chloride with 2 parts of sodium chloride also forms an active low melting flux which is said to have properties superior in certain respects to the zinc chloride-ammonium chloride mixtures, especially for use in dip soldering or as a fused salt flux. These same salts are the basis for many proprietary fluxes which are sold under various trade names. One such flux, Eureka No. 32, sold by the Canadian Industries, Ltd., Box 10, Montreal, Quebec, Canada, is particularly effective with the low-tin solders. Paste-fluxes usually contain zinc chloride or other active flux in Vaseline,

Some metals such as nickel, Monel, stainless steel, and dirty galvanized iron are difficult to solder even with the zinc chloride-base fluxes. The addition of up to 50 per cent of hydrochloric acid aids in fluxing these metals.

Alloys containing readily-oxidized elements that form light coherent films (such as aluminum and silicon) present a special problem.

The zinc chloride-hydrochloric acid fluxes will not dissolve aluminum oxide or silicon oxide films. However, the addition of up to 5 per cent of hydrofluoric acid forms a flux that removes the oxide film and makes soldering these alloys possible.

Another interesting development in fluxes is the use of "wetting agents". Fluxes, to serve their purpose, must reach the surfaces to be soldered but often, because of grease or oil, the solution will not wet the metal and will not penetrate joints. The addition of a small amount of the wetting agent (such as Tergitol, Triton NE, and many others) frequently overcomes this condition. Since alcohol is itself a wetting agent, such additives are not needed in alcoholic solutions. Inhibitors are sometime added to acid fluxes, also, to decrease corrosion, but they are not always effective in practice.

Residual acid flux should be removed from the joint after soldering by thorough washing. Since insoluble zinc oxychloride is readily formed by the action of water alone on zinc chloride, a preliminary wash with a dilute (one or two per cent) muriatic acid solution is desirable before flushing freely with water.

Relatively Noncorrosive Fluxes

Fluxes are commonly classed as corrosive or noncorrosive, depending on the action at room temperature of the residue left after soldering. To be of any value as a flux, however, a substance must be capable of exerting some positive oxide dissolving action at soldering temperatures.

The fluxes just discussed are corrosive at room temperatures and leave residues that are corrosive, hygroscopic, and conductive. They are unsuitable, therefore, for most electrical work and other applications where residues cannot be removed by washing and corrosive action cannot be tolerated.

Rosin, or rosin in alcohol, has long been accepted as the only noncorrosive flux suitable for use in the electrical industry. The corrosive action of thin residues left from soldering with rosin flux is very slow, and long periods of time are required for any attack to be noticeable. Residues are nonhygroscopic and nonconducting. In general, rosin is also the least destructive of all soldering fluxes at soldering temperatures. For this reason, it is preferred for the soldering of fine copper wires and other intricate work.

Much effort has been expended in the search for a flux that would be noncorrosive, nonconductive, and nonhygroscopic, and yet have better fluxing action than rosin. As a result, many mixtures have been developed that are not so corrosive as the zinc chloride-base fluxes and approach the desirable properties of rosin. These include stearic acid, naphthalene tetrachloride, aniline, and other nitrogenous compounds (sometimes in combination with hydrochloric acid) and lactic acid, phthalic acid, or phosphoric acid, alone or mixed with tallow, rosin, or petroleum jelly. Various amines and amides also have been proposed. Mannitol mixed with rosin is considered by some to give a better fluxing action than rosin alone and is noncorrosive.

Such materials as Gallipoli oil, olive oil, tallow, and some modified mineral-base oils are in this general classification, also. Those substances are satisfactory for soldering lead, pewter, tin, and sometimes clean copper-base alloys. They are relatively noncorrosive and have mild fluxing action. Unfortunately, many of these less corrosive fluxes decompose too rapidly at the temperatures needed where using low-tin solders, or their action is too mild; hence, as a class they' are less important under present conditions than inorganic acid or salt fluxes. When using readily solderable materials such as tin plate, even the mild fluxes are effective with low-tin solder, however.

Salt Baths:

Fused salt baths have 'come 'into use recently-for the preparation of such metals as cast iron, malleable iron, and others 'that' are difficult to tin or solder. These usually consist' of zinc chloride 'to which have been added one or more salts such as 'sodium, 'potassium, and ammonium chloride in amounts up to 10 per cent' each.

DESIGN OF JOINTS

A full discussion of joint design would require far more space than can be allotted here, but a few fundamentals warrant mention. It has been demonstrated repeatedly that joints have the greatest strength when the solder film is 'between 0.003 inch and 0.005 inch in thickness. More space between the parts to be 'joined not only decreases the strength, 'but also wastes solder. On the other hand, joints must allow sufficient space so that the solder can flow between the surfaces. Heavy fillets add little strength and waste solder.

Since solder is almost always weaker than the metals being joined, it' is advisable, whenever possible, to design joints with lock seams or rolled joints, or to tack, braze, spot weld, rivet, or use the special type of screws designed for joining sheet metal. Solder, then can be used to seal the joint, and frequently, since strengtn is not required from the solder, an appreciable saving can be realized.

Forms of Solder Available

Solder is sold by most suppliers in a variety of forms suited for different methods of soldering and application of heat. For example, tinmen use solder in the form of triangular sticks about 15 inches long and weighing about l/2 pound. Plumbers solder is sold in heavier bars about 7/8 inch wide by 13 to 16 inches long. Slabs or ingots for use in dip soldering or wiping commonly weigh about 25 pounds or more.

Wire in various sizes up to about 3/16 inch in diameter in spools weighing up to 50 pounds is a popular form,. This wire is available solid or cored. The cored wire is a hollow tube filled with flux, either rosin or an acid paste. Square wire, as well as a round shape, can be produced.

Solder pastes, which are mixtures of powdered solder and flux, powders, foil, washers, end many other special shapes are also available. In metal spraying solder over clean roughened surfaces, spray guns for using solder wire or for using a molten bath are available.

APPLICATION OF HEAT

Copper Bit or Soldering Iron

The copper bit or soldering iron heated in a salamander, blow torch, furnace, or internally by electric resistance, is the most common method of applying solder and,in many cases is the most efficient.

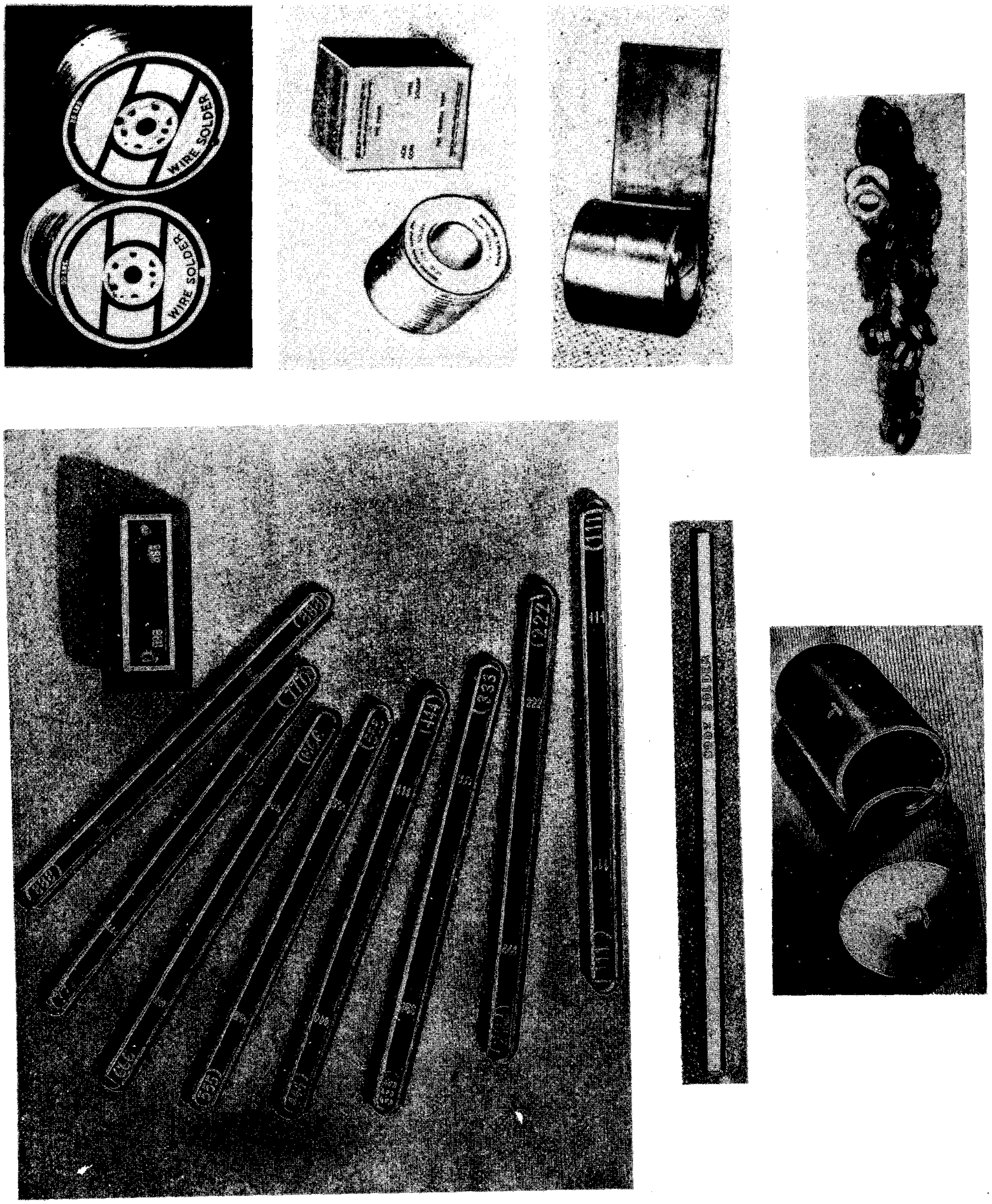


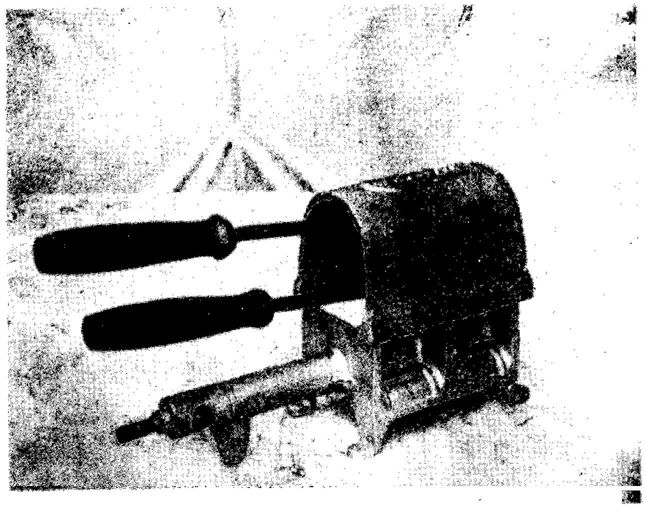
Figure 1. Some of the available forms of solder.

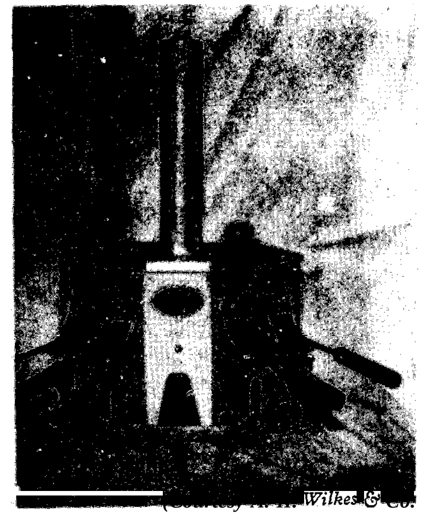
It is important to design the iron for the work being done. It must be remembered that, although sometimes it is necessary to transfer the heat to the work by means of the solder, the work itself must be brought up to the melting temperature of the solder before the solder will wet the base metal and form a proper joint. The first requirement of the soldering iron, then, is to heat the metal parts of the joint; melting and distributing the solder is the final step.

The solder, itself, is a very inefficient agent for transferring heat, and when so used, the solder must be heated much hotter than would otherwise be necessary. This leads to excessive oxidation of the solder. and the formation of dross. Copper bits are also worn out faster by the excess heat. In many cases this can be avoided by designing the iron to fit the work, In others a different method of applying the heat or pre-, heating is advisable.

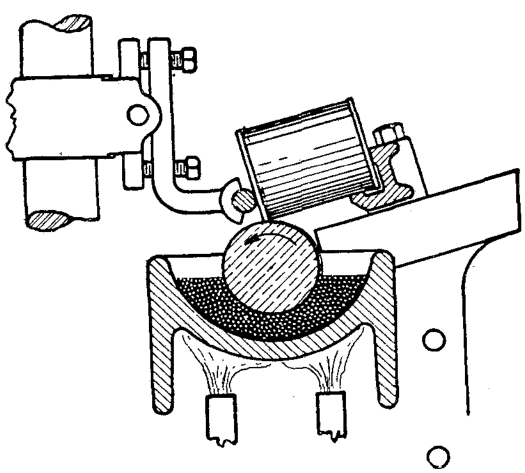
Salt baths have been tried for heating soldering irons and may have advantages, The copper bit would thus be protected from oxidation,. In practice, the iron is removed from the salt, dipped momentarily in water (which explodes the salt from the iron), and is then used in the normal manner.

It must be remembered that the low-tin and tin-free solders require a markedly higher heat than the formerly used tin-lead solders. This demands much more of soldering irons, both in wear and- in frequency of reheating. Although this means of soldering is still effective, other means of heating should be considered when using the low-tin solders.

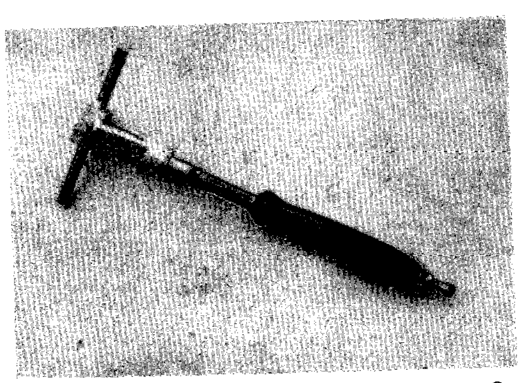




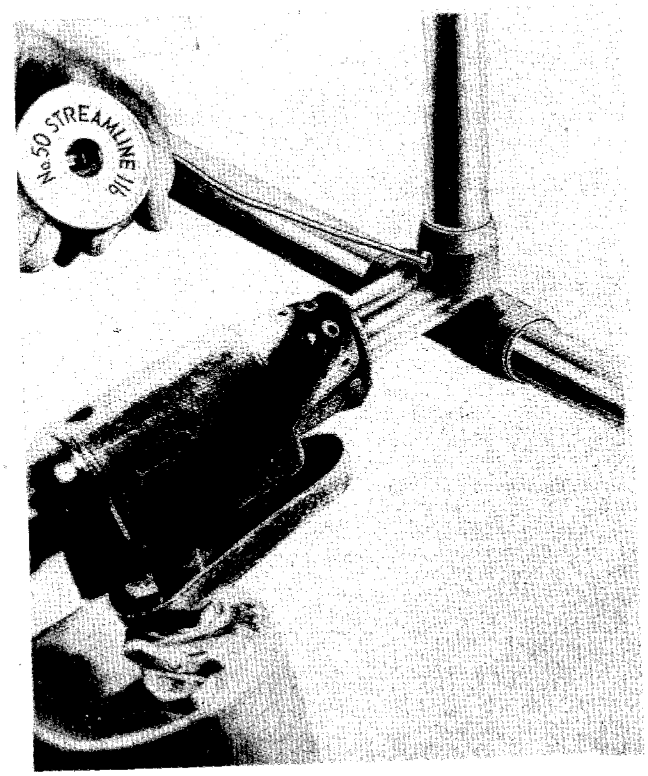
(Courtesy A. H. Wilkes & Co.



(Courtesy Cameron Can Machinery Company)



(Courtesy A. H. Wilkes & Co.



Courtesy of the Mueller Brass Co., U.S.A.

Figure 2. Methods of applying heat in solderiing.

Torches

Since restrictions have been placed on the use of tin, and low-tin solders with higher melting temperatures must be employed, the use of torches in soldering has increased greatly, Many of the disadvantages connected with copper bits have thus been eliminated: Interruptions in re-heating or changing bits are overcome and a more uniform source of heat is, maintained.

In addition to supplying heat more rapidly, work 'does not have to be stopped for reheating or cleaning of the soldering iron. The base metal can be heated to temperature more rapidly, and higher temperatures can be attained, which is an advantage in using low-tin solders, 'Overheating, however, should be avoided..

Surfaces to be soldered can be prefluxed and solder preplaced, or solder can be added as in brazing or welding. With either method, the heat is applied directly to the base metal until the solder flows towards the heat. Direct contact of the flame with the solder should be avoided. Where possible, if preplaced solder is not used, it is good practice to apply the torch to one side of the joint and draw the solder to it from the other. This precludes entrapment of flux and indicates that the base metal has reached soldering temperature,

Many different types of torches are available, some burning gas and air, acetylene and air, or gas and oxygen, and acetylene and oxygen. All can be used satisfactorily. For high speed soldering, the gas-air mixture is least desirable, however, because of lower flame temperature. It has been reported that gases having a high hydrogen content are to be preferred over plain methane-type gases when using lead-silver solder. This is probably because of the high flame temperature and -high rate of 'flame propagation obtainable with a hydrogen enriched gas. Carbureted water gas is a better fuel

Bit soldering and blowpipe soldering of miscellaneous parts in radiator sub-assembly operations

[Courtesy of Long Manufacturing Division –Borg-Warner Corporation

Figure 3. A soldering method.

Figure 4. Torch soldering gasoline tanks.

oonsequently, than natural gas because of its hydrogen content. This is easily produced also by mixing hydrogen with natural gas through a mixing valve.

Furnace Soldering

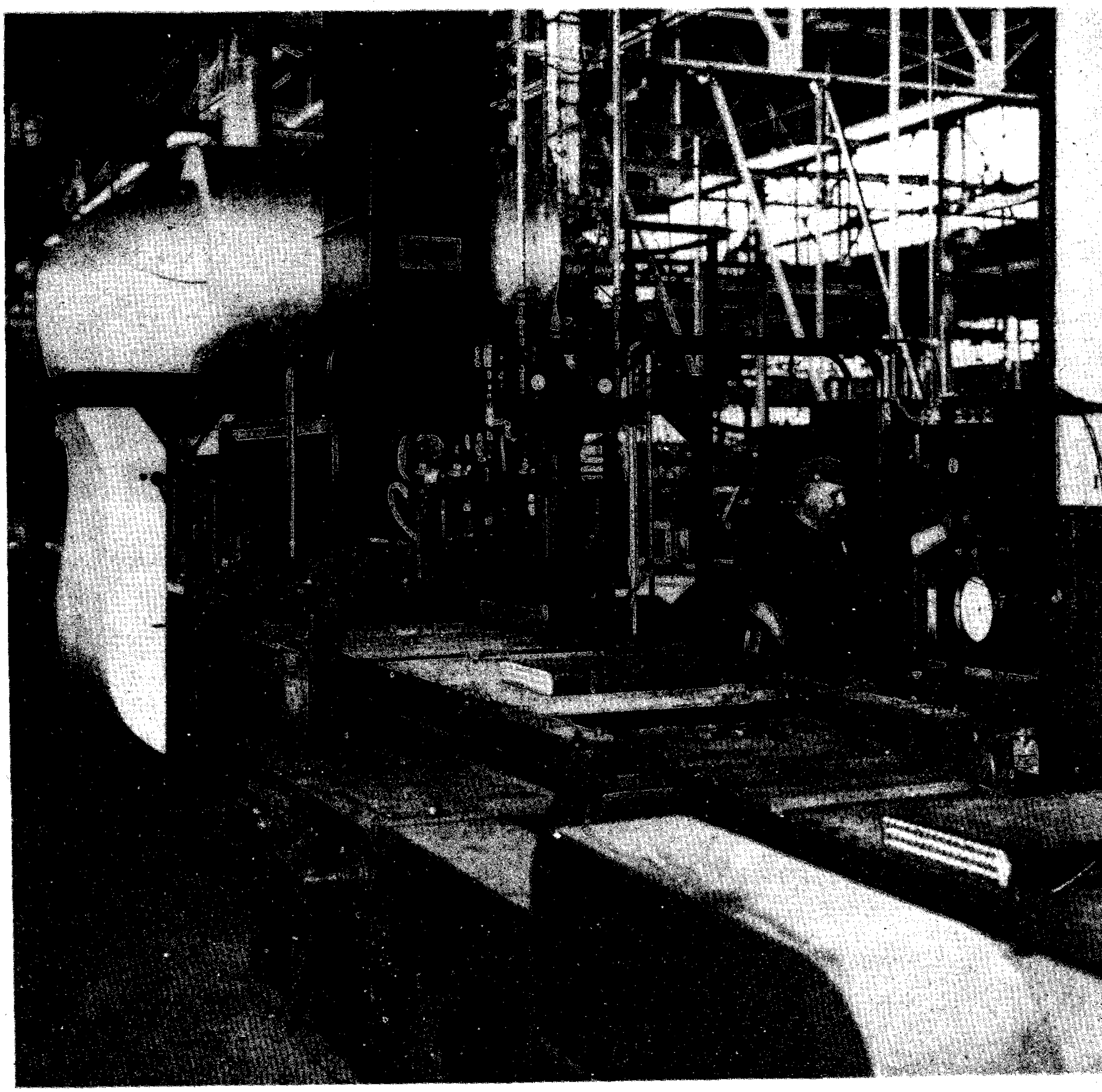
Furnace soldering is now used to a limited extent, and probably is applicable to a much wider field. Success of this method depends on proper design of joints and preplacement of the solder, so that it is drawn into the joint. Furnace temperatures time in furnaces and jigs for holding the pieces to be soldered during heating and cooling must be developed for each application.

Since the temperature of soldering is too low for active reduction of oxides by hydrogen or carbon monoxide, there is little to be gained by using a special furnace atmosphere as in furnace brazing. This simplifies furnance construction and operation.

Electric Resistance

Carbon resistor heating units are clean and economical since electricity is used only while objects are being heated. These units, consisted of two carbon electrodes mounted for convenience in holders, jigs, or pliers to grip the work. Heat is generated principally in the carbon electrodes which transfer the heat to the work. Flux and solder are applied in any convenient manner after the parts have reached soldering temperature;

This method is rapid and provides good control, but the control, installation, and operation is not as foolproof as the use of bits or torches. Also, application is limited to work that can be designed to



Automatic soldering of motor vehicle radiator assemblies (Courtesy: Westinghouse Electric & Mfg. Co.)

Figure 5. An example of furnace soldering.

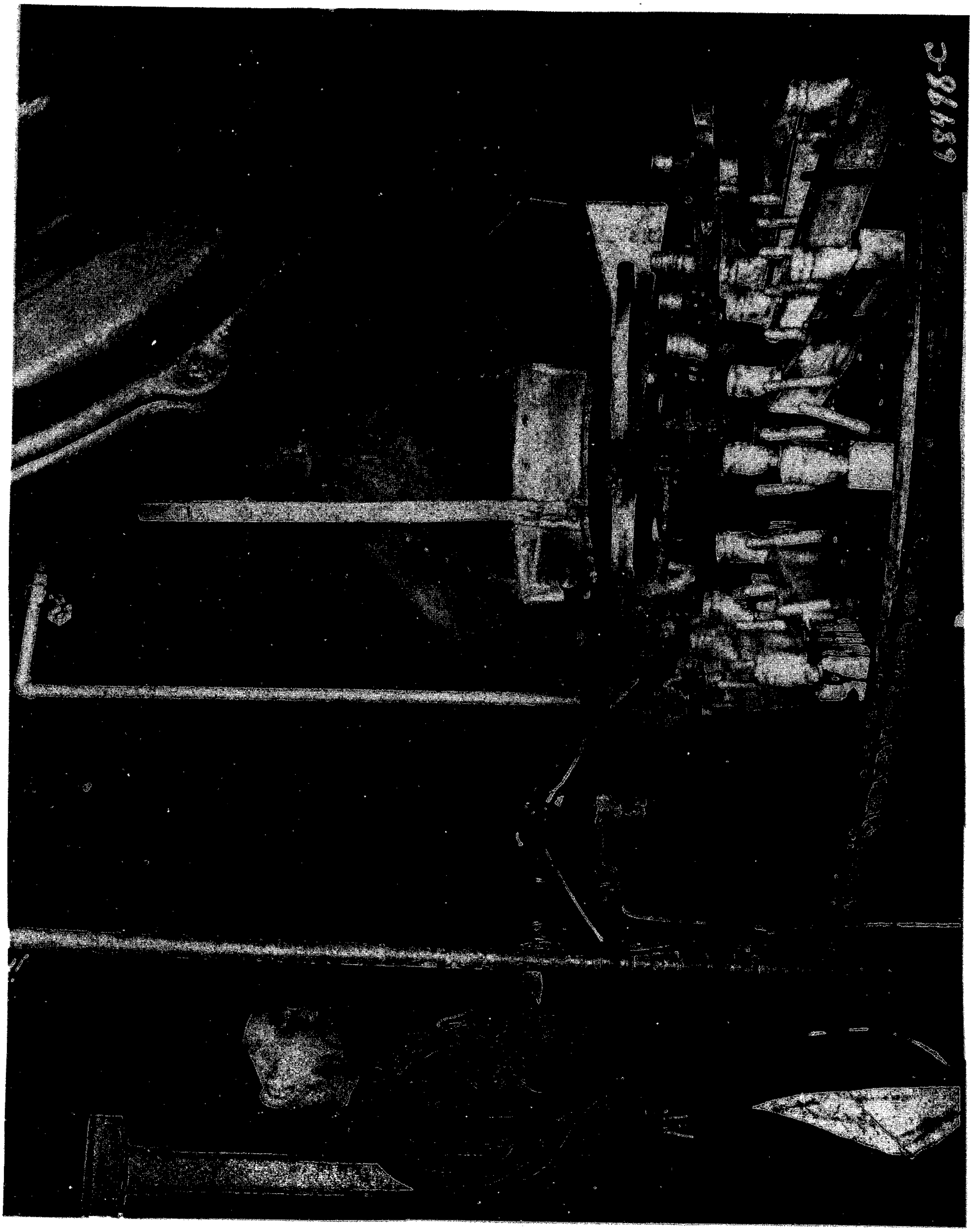


Figure 6. Furnace soldering. Radiator part is heated in the furnace, and solder applied by hand after the part leaves the furnace.

be heated between electrodes.

Induction Heating

Induction heating is a relatively new method that is rapidly gaining in popularity. More equipment and technical maintenance is required, but rapidity and ease of operation readily offsets disadvantages. The work has to be such that it can be inserted into the field of a high frequency coil. Beyond this there are no limitations. No electrical connections to the work are required, and any flux or solder can be used. Heating is very rapid and clean; in many cases, the surfaces or areas to be soldered can be heated to soldering temperatures without the bulk of the object becoming hot.

Solder can be preplaced or it can be applied after the work reaches soldering temperature; In the simplest operation, solder is laid in or near the fluxed joint, the' object is placed in the field, the current applied momentarily, and the work removed. This method performs equally well with low-, and-high-tin solders, since there is no limit to the available heat, end the temperature can be controlled by timing. Specially shaped coils may be designed which permit the use of continuous belts to convey parts to be soldered through the induced field. This 'has eliminated one objectionable feature, the necessity for placing the object within a coil or a coil around the object.

Dip Soldering

Dip soldering has proved an effective method for securing sound joints and is widely used. This method is applicable to two types of

Figure 7. Soldering with induction heating, using a specially designed coil. Courtesy of RCA and Electronics Magazine, Reference 16.

work: (1) where the entire object is to be coated with solder, thereby combining the forming of strong and often leak-proof joints with the protective coating of a base metals and (2) where only one end of a joint is dipped into solder, whereby the entire object or a sufficient portion will be heated hot enough so that solder will be drawn into the joint by capillary action,

Objects to be soldered are cleaned by degreasing and usually by immersion in a sulphuric or muriatic acid bath kept at about 150°F. followed at times by dipping into zinc chloride solution fluxes, Fused salts, (see discussion of salt baths for fluxing), are also used for cleaning and fluxing. They have the advantage of preheating the work almost to soldering temperature before contact is made with the solder,

In dip soldering, some precautions must be taken, It is essential to have' a solder bath sufficiently large so that the work, whether preheated or cold, does not chill the solder bath to any appreciable extent. If the bath is chilled, the process of soldering is not only slowed, but an excessive amount of solder is consumed unnecessarily. Directly related to the ratio of work to the size of the bath is the amount of super heat necessary, The bath should be hot enough to insure rapid heating of the work to soldering temperatures, but. care should be taken to prevent overheating. Normally about 90°F. above the initial melting temperature (liquidus) is sufficient.

This method of soldering has been extensively used in soldering heat exchangers, including automobile radiators. Low-tin solders can be successfully used; in fact, pure lead has been used in dip coating, and lead containing a few per cent of antimony and a per cent or two of tin

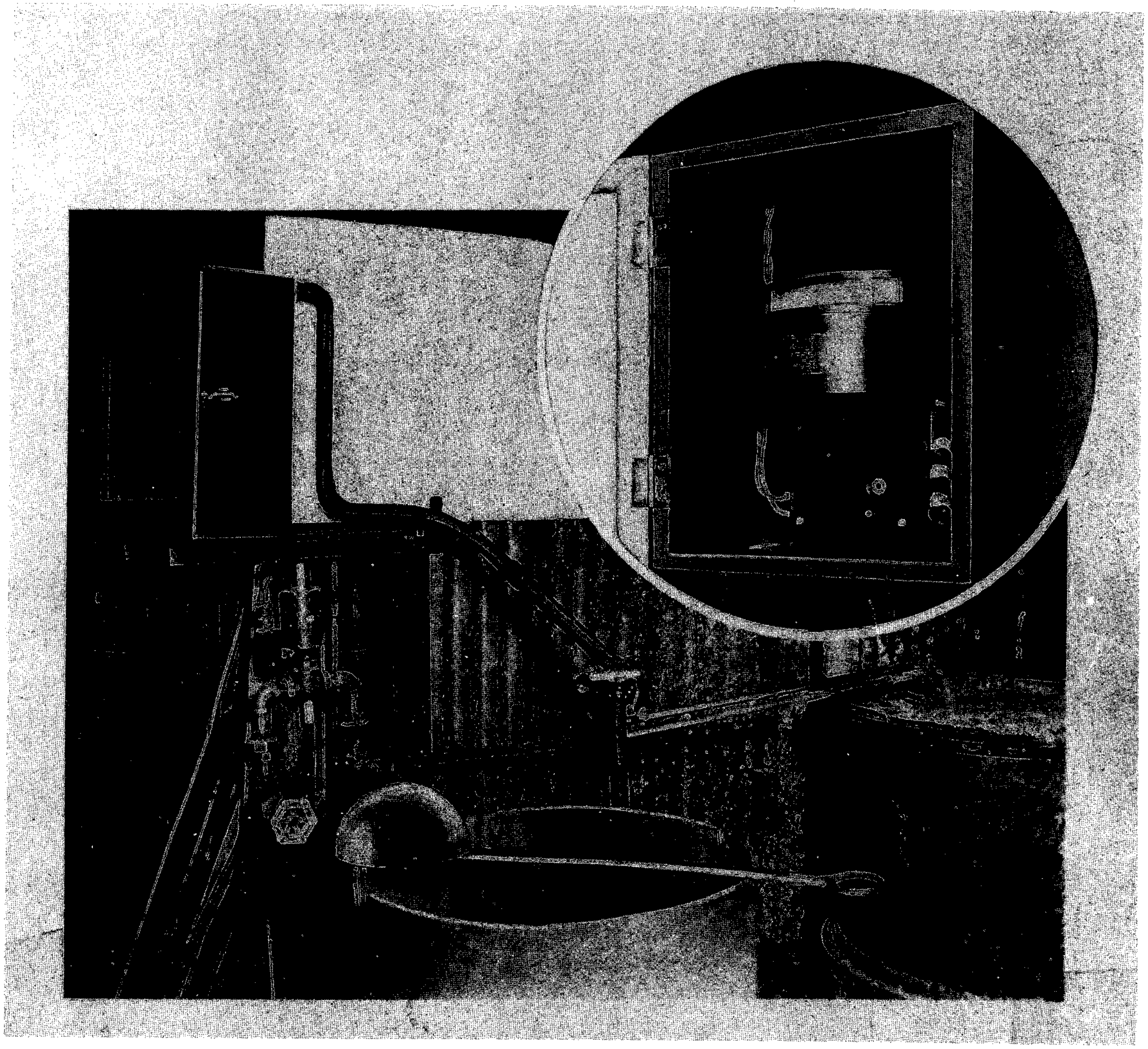


Figure 8 Showing temperature controller for dip-soldering pot.

is commonly used in coating steel strip and sheets. The disadvantage (in using tin-free or low-tin solders) of having the higher temperature seriously lower the hardness and strength of cold-worked brass usually can be overcome by holding the time at high temperature to a minimum and by adding to the brass small additions of silver, cadmium, columbium, or certain other metals which prevent excessive annealing.

An advantage in using a tin-free or low-tin solder in dip soldering copper-base materials is that contamination by copper is much less than with normal tin-lead solders.

EXAMPLES OF INDUSTRIAL PRACTICE

Solders are used in such diverse applications that it is impractical to cover even the important uses. From the general characteristics of the solders, fluxes, methods of preparation, and means of soldering, which have been discussed, the choice of materials and methods for a given application should not be too difficult. Some industries have converted quickly and effectively, to substitute solders, as exemplified in the use of silver-lead solder by the can-making industry. Others have had difficulties.

As examples of industrial applications, practice in the electrical industry has been selected because of its importance of the different conditions which must be met; the sealing of vent hole evaporated milk cans is described because of difficulties in using high-melting solder for a very rapid operations; and the soldering of galvanized material is briefly discussed because it represents a widely scattered application where poor practice in using low-tin solder and substitution carried too far can do more harm than good. Surveys have been made recently of soldering practice in these industries.

Electrical Industry

The amount of soft solder used in the various divisions of the electrical industry is not large for each application, but the number of applications is so great that the total amount of solder used is quite important. Fortunately for purposes of consumption control, most of the electrical equipment manufacture is in the hands of companies sufficiently large to support well-organized technical staffs which can supervise adoption of lower-tin solders wherever such usage is practical. Thus, the industry noticeably felt the effect of the first tin conservation order, but the more recent restrictions to 20% tin in solder for general use seemed less drastic since steps already had been taken by the largest companies to use solder of minimum tin content.

While the greatest proportion of the products now being made by the large electrical companies comes under the heading of "Implements of War" and are therefore not subject to the conservation order, a real effort has been made to save tin in all applications. This has been done by placing a maximum on the tin content of solders for general use and by requiring approval of company conservation committees for all requests for higher tin content solders for special applications.

The chief function of solder in the electrical industry is to furnish a metal-to-metal contact for current-carrying applications which will not be loosened or affected by vibration, and which will prevent formation of oxide films or corrosion films that cause poor contact, Secondary functions are to form mechanical joints and to form a protective layer on some metal surfaces.

Electrical Manufacturing Industry

In the past, pure tin, 60 Sn - 40 Pb, and 40 Sn - 60 Pb solders have been widely used. Recently these have been largely replaced by solders similar to those listed in Table 3.

TABLE 3: SUBSTITUTE SOLDERS COMMONLY USED IN THE ELECTRICAL INDUSTRY

	Nominal Composition	Softening Point, ° F.	Fluid Point, °F.
1.	97.5 Pb, 2.50 Ag	579	579
2.	90.0 Pb, 10 Sn	527	566
3.	84 Pb, 15 Sn, 1 Ag		-
4.	77.75 Pb, 20 Sn, 1.25 Ag, 1.50 Sb	352	503
5.	66.75 Pb, 30 Sn, 2 Sb, 1.25 Ag		

Solder No. 1 is recommended chiefly for applications where high rupture strength is required at elevated temperatures. This solder does not flow or wet so well as pure tin, but can be used effectively with corrosive fluxes. If surfaces to be soldered are pretinned or cadmium plated, resin flux can be used. A major use is in the soldering of rotor binding bands. A small amount of copper, as 0.25%, is sometimes added to this solder, but it is not essential.

Solder No. 2 is used for pretinning or dip soldering in solder pots. Corrosive zinc chloride type fluxes and careful washing to remove the flux after soldering are recommended.

In a few applications, particularly where higher temperatures are involved and more corrosive fluxes are not objectionable, solder No. 3 can be used, but only where there is no danger of burning insulation, and softening of copper is not critical.

For a general all-purpose solder to replace 40 to 50 percent tin solders, the No. 4 solder is recommended. It can be used with noncorrosive fluxes, such as resin or aniline phosphate, on bare or precoated copper, but a corrosive flux is usually required for bare steel; Rupture strength at elevated temperatures was found to be better than for 40 to 50 per cent tin-lead solders. This solder can be used in wire form, resin cored, or solid, for the majority of electrical connections which formerly were made with 40-60 to 60-40 tin-lead solders.

Since the 20 per cent tin solder melts at a temperature about 35°C; higher than the 40 percent tin solder, it has been found necessary to use hotter soldering irons; that is, a 100-watt iron is needed where an 80-watt iron formerly sufficed. This higher temperature increases the oxidation of the copper, but is offset to some extent by the slower erosion or alloying of the copper with the tin in the low-tin solders. This solder is also used in larger soldering pots in place of 40-60 solder for soldering armatures. Recently, the composition of this solder has been changed slightly, and specifications now require 19.5 to 20.5 Sn, 1.15 to 1.35 Ag, 1.25 to 1.75 Sb, 0.75 maximum Bi, 0.005 maximum Al, 0.005 maximum Zn, and balance Pb.

Solder No, 5 is used for wiped joints. It handles well, but is more susceptible to porosity than 40 Sn-60 Pb solder.

The use of high-tin solders has not been entirely eliminated, sometimes because of engineering reasons related to the characteristics of the solder, and sometimes because of government specifications. A notable example is the soldering of winding leads to commutators. For many high temperature applications such joints are made with pure tin. Where the temperature requirements are not quite so stringent, 20 per cent tin solder is used and, when applied with the proper technique, gives good joints. The Bureau of Ships, however, specifies 60 per cent tin solder for the type of connections in question.

Much progress has *been* made with brazed joints, particularly for commutator riser joints and armature winding joints using copper-silver phosphorous or copper-phosphorous alloy. This development, of course, eliminates the use of all tin for such joints. Unfortunately, however, not all commutator joints can be brazed because of space limitations and inability, with the present development of brazing tongs to heat the joint. The use of brazing for these joints is no small item and has practically superseded soldering on all large motor generator sets.

Silver-lead solders have been tried on commutator-winding joints, but corrosive fluxes cannot be used, and resin flux does not promote flowing sufficiently to give sound joints.

Tin-base solders containing 60 per cent tin are used in the making of lock and lap seams. The 20 per cent maximum solders have been tried, but results have not been too satisfactory because leaks are apt to form in the seams, and on capacitor cans one small leak is enough to change characteristics and spoil the capacitor. A 60-40 solder is being used on this job, but work on other compositions in combination with special processes, such as high-frequency heating, is in progress. In some cases where porcelain is involved, the eutectic solder is desirable. Both 40-60 and 60-40 solders are used in the production of transformer cans. Again, 20 percent tin solder has been tried, but close production schedules do not leave sufficient time to sweat 20 per cent tin holder into the seams or joints.

Solder containing 40 to 60 per cent tin is still being used by makers of small instruments, but work is very fine, joints are pin-point in size, and only very small amounts of solder are used. It would be impractical if not impossible, to use low-tin solders on such applications,

4

The soldering of zinc-coated articles require corrosive fluxes regardless of tin content in the solder, Sometime ago it was requested that cadmium-plated parts be zinc plated in order to relieve the situation on cadmium, but corrosive fluxes could not be used and therefore cadmium is being used where plating is necessary. It has been found that cadmium-plated parts can be satisfactorily soldered with low-tin solder using resin flux provided the parts are not stared for long periods,

High-tin solder (38% tin) is still used for wiping the ends of oil- and gas-filled cables. Tin conservation is accomplished by using wipes requiring much less material than formerly, bu the 38 tin solder is deemed necessary to eliminate any possibility of defective cables, since one small leak could ruin the entire cable. Some companies are using successfully solders containing only 32 per cent tin for wiping certain types of cables.

Aside from the effort put forth in the field of soldering, the possibilities of redesign, completely eliminating the use of solder, should not be overlooked. One idea which has been actively developed by one company is the use of a drawn metal container with a mechanically double seamed cover, similar to that used in the food packing industry, for a capacitor casing. All solder used in building the usual can would thus be eliminated. While it is difficult to introduce radical changes in manufacturing procedures during times when the major objective is to deliver finished apparatus, it has been possible, slowly but diligently, to prosecute the development of a double seamed type of capacitor container which might be the forerunner to subsequent changes in the design and manufacture of capacitors. Another example is the development of a solderless type joint for electrical connections. Redesigning in many cases might result nat only in the saving of solder, but also in manufacturing of a better product.'

Communication Equipment

Most of the communication equipment manufacturing capacity is being utilized in the production of instruments for the armed forces. In addition, the work involves the making of 'fine intricate joints, such as those in switchboards, radios, radar, etc., and the connection of parts that often require replacement. Such joints must be so made that defective parts can be 'replaced easily in the field.

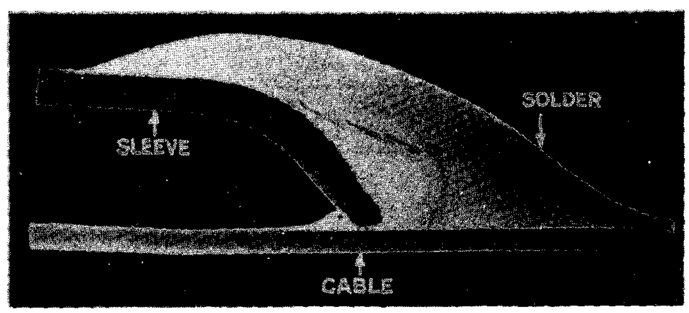
In work of this kind noncorrosive, nonconducting, and nonhygroscopic fluxes must be used, and temperatures must be kept low in order to avoid the burning of insulation. To 'meet these conditions and also obtain ease of replaceability solder containing 40 or 50 per cent tin is used.

However, for noncritical. applications, it is possible by observing certain precautions to accomplish such work with low-tin solders, In some cases, by tinning parts to be soldered before the joints are made, low-tin solder will prove satisfactory. This conceivably can take more tin than using a higher-tin solder, unless pretinning is done electrolytically or the tinning is done with a low-tin solder. In other applications, hotter irons applied for longer times overcome the difficulties presented by higher melting points and poorer wetting properties,, Where joints can be washed with alcohol after soldering, a napthalene tetrachloride, aniline phosphate , or resin and stearic acid flux can be used.

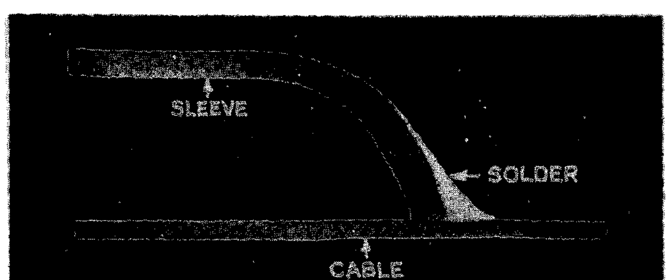
In the field of telephone equipment and cable manufacture, the biggest savings probably have been made in the redesign of joints, whereby a small fillet-wiped joint replaced a large ball joint (Figure 9). The solder preferred for this work contained 38 per cent tin, 0.1 per cent arsenic, 0.5 to 2 per cent antimony, and the balance lead. Other alloys containing small amounts of antimony and lower tin contents are being introduced. A stearic acid flux is preferred for wiped-lead cable joints, as the excess flux is removed by burning.

Solders containing 20 per cent tin and some as low as 15 per cent are commonly used for miscellaneous dip and hand soldering work, particularly if a zinc chloride type of flux can be used.

Pure lead is used in place, of galvanizing or terne coating for many articles which can be hot dipped. These coatings can be soldered with low-tin solders much more easily than zinc coatings. A 4 Sn -96 Pb



—SECTION FROM JOINT WIPED CONVENTIONALLY. × 1½.



—SECTION FROM JOINT WIPED BY FILLET TECHNIQUE. × 1½.

Figure 9. Old and new designs in wiped cable joints. (Used with permission of E. E. Schumacker and A.I.M.E., Reference 15)

alloy has been used in making joints subjected to only small stresses and where the temperature of operations is too high for the more common tin-lead solders.

Soldering Galvanized or Zinc-Coated Material

The soldering of zinc-coated material is much more difficult than the soldering of such metals as copper and iron. However, with sufficient care and attention to soldering technique, even low-tin solders can be used successfully, although more time is required in the operation.

Wherever joints must be leak proof; solder containing 40 per cent or more tin is much more reliable. Nevertheless, it must be remembered that high tin alone will not insure good joints, Antimony in any solder brings disaster when zinc-coated materials are being soldered. Such joints made with antimony-containing solder are brittle and have no resistance to shock and little resistance to stress.

Some of the substitute solders such as a lead-base alloy containing 8 percent cadmium and 2 per cent zinc are being used successfully on zinc, especially in Germany, but the shortage of cadmium limits its use in solders in this country.

Low-tin solders can be used by observing the following precautions:

1. Use a tin-lead solder which is free from antimony. Avoid any antimony-containing solder when soldering zinc or galvanized iron.

2. Use a flux high in ammonium chloride, such as one of 28 parts ammonium chloride, 73 parts zinc chloride, and 400 parts water.

3. In case the zinc coating is dull, as on old used material, add a little free hydrochloric acid to the above flux to insure the removal of zinc carbonate;

4. Do not heat the parts to be soldered too hot. A temperature just hot enough to flow the solder is all that is needed. High temperatures oxidize the galvanized surface forming oxychlorides which cause the solder to "ball-up" or fail to wet the sheet. The low-tin solders, however, require higher temperatures than the high-tin solders.

5. Wash the finished joints thoroughly with water or very dilute hydrochloric acid followed by water to remove excess flux.

As in the soldering of any metal, the possibility of using different heating methods should be considered. Metals heated rapidly to soldering temperatures have less time to oxidize and therefore solder more easily.

Tipping or Sealing of Vent Hole Evaporated Milk Cans:.

The tipping or sealing of vent hole evaporated milk cans, is illustrative of special types of soldering. Because of the speed of operation, from 120 to-180 cans per minute, soldering and sealing must take place almost on contact of the iron with the can. In order to seal cans successfully, all conditions must be under control. Regardless of the solder being used, the hole of, the can will not be closed if the filling and tipping machines are not running smoothly. This means that tipping irons must be properly centered and free from vibration. The cans should not be shaken or vibrated either on the filling w&eel or on being transferred to the tipping wheel. Foaming milk which gets on the prongs of the filling hole, or milk that has splashed onto the prongs must be removed, for solder will not adhere to metals covered with charred organic material.

High-tin solder performed very satisfactorily in sealing cans, and because of its low melting point and affinity for tin plate, greater flexibility and less rigid control was permissable. Low-tin solders, such as those containing 20 per cent tin and minor additions of antimony (usually 0.5 to 1.5 per cent), can also be used successfully in the sealing of vent hole cans with little, if any, reduction in rate- of operation. One condensery is operating a filler at 172 cans per minute with modified 20 per cent tin solder. Many are having no trouble using the same type solders at speeds between 100 and 160 Cans per minute. It has also been reported that one plant on the west coast has been experimenting with a solder containing only 5 per cent tin, 5 per cent antimony, and the balance lead with good results.

In using these low-tin solders, however, it is necessary to exercise more rigid control. The filling and tipping machine itself must be in good condition, Foaming milk is even more troublesome than when high-tin solders are used.

When good operation of the machine itself is assured, a few modifications in technique should be made, Normally, after the can leaves the filling wheel, it is sprayed with water and steam to remove milk, and flux is applied to the edges of the hole by means of a wick or flux well and brush. Then the tipping iron meets the vent hole and applies the solder.

In most plats, when the change was made to low-tin solder, it was found necessary to insert a preheating flame (sometimes called a backfire) to dry the can top and to aid the tipping iron in heating the edges of the vent hole to soldering temperature. This was necessary because the melting point of the low-tin solder is much higher than that of high-tin solder (510°F, as compared to 420 to 450°F. for 40 and 50 percent tin solder). To be most effective, this flame is usually applied between the flux applicator and the tipping iron. Adjustments to the tipping iron, also help. A shorter lift seems to be beneficial. Also, the point at which the solder is fed, both on the iron and in the travel, can be varied.

Automatic controllers to control the temperature of the tipping iron have greatly improved the operation of closing vent holes. These controller systems consist of thermocouples placed in the center of the tipping iron (through the spindle), pyrometric or potentiometric controllers, and solenoid valves to control the air, and gas flow. In some cases, the gas and air are premixed and one valve is sufficient; in others, valves are needed for both gas and air lines. Regardless of which system is used, better control can be obtained when enough gas and air are by-passed to heat the iron to a temperature several degrees below that desired, and the solenoid valves are used to increase the flow and raise the iron to soldering temperature. This eliminates the wide variation found when the gas is cut off completely by the automatic system.

When the tipping operation seems to be functioning properly and good seals are not obtained, it is advisable to inspect the condition of the vent hole to be sure that the shape of the hole is correct and that milk is not getting on the prongs. When the prongs and edges of the vent hole are clean and the above precautions are observed, satisfactory results can be obtained with the modified 20 per cent tin solders.

TIN CONSERVATION IN SOLDER IN OTHER COUNTRIES

The United States is not the only country which has taken steps to curtail the tin content of solder, of course and mention should be made of the efforts of others in regulating tin solders in the electrical industry.

A report on "Substitute Solders" by E. H. Tover which has been distributed widely by Canadian Westinghouse Company is of particular importance. This company has found only a few minor applications where high-tin solders must be used, and they particularly stress the need for developing soldering technique to handle the low-tin or substitute solders. Use of a gas flame in place of a soldering iron has helped greatly in many instances. Aside from the tin-free 2.5 Ag - 97.5 Pb type of solder which requires an acid flux, a 15 Sn - 1 Ag - 54 Pb solder with resin-alcohol flux is advocated. For very fine work with delicate insulation, a 20% Sn - 1.25Ag - 0.5 Bi - 78.25 Pb solder is advocated. This is used for switchboard wiring and general maintenance work.

In Australia, a solder of 88.5 Pb - 10 Cd - 1.5 Zn has been considered the best substitute for tin-lead as a general purpose solder for the electrical industry, according to a recent report(1). This alloy

(1) Investigation of Low-Tin and Tin-Free Solders. H. W. Worner, H. T. Greenway, and J. K. Buckley, Commonwealth of Australia, Council for Sci. and Ind. Res., Div. of Ind. Chem., Ind. Chem. Circ. No. 2, 1943.

may be modified by addition of 5 per cent tin for general work where a wide solidification range is satisfactory. For a wiping solder, however a 65 Pb - 25 Sn - 10 Cd alloy is suggested,

German practice also appears to favor cadmium-lead solders with 88 Pb - 10 Cd - 2 Zn considered desirable for general purpose work. Such a composition is particularly good for soldering zinc parts or galvanized joint members.

In England, possibilities in saving tin by using less solder per joint rather than a lower tin content solder have been suggested.(1) Savings of 67 per cent to 90 per cent were demonstrated in soldering lead-sheathed cable by changing the joint design. Likewise, the joining of formed lead pipe with prefluxed solder foil was said to save around 99 per cent of the solder commonly used. Use of fused salt fluxes have been investigated and recommended. Dip sold&r of about 20 per cent tin and 1 per cent antimony has been found practicable in some cases for oar and truck radiators.(2) Substitute solders recently tried include some containing 12% or less tin and 4-8, % antimony.

CONCLUSIONS - PRECAUTIONS IN GOING TO LOW-TIM AND TIN-FREE SOFT SOLDERS

The successful use of low-tin solders, or for that matter any solder, has been found to depend on, close attention to technique. The following points have been stressed(3) as of the utmost importance in effecting a change to a low-tin or tinless solder because greater care is needed to obtain satisfactory results with them.

1. Keep your work clean. Varnish, grease, oil, dirt, rust, or

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(1) Economy of Tin in Solder. Tin and Its Uses, July 1942, pages 3 to 5.
(2) W. R. Lewis. Tin and Antimony in Lead Alloys.
(3) Bulletin of the General Committee on Metallurgy, Vol. 3, No. 6 (General Electric Company).

corrosion products cannot be too carefully guarded against. Any of these will prevent the flux from acting and will prevent the solder from alloying with the parent metal.

I. 2. Keep in mind that the purpose of the soldering iron or torch is not to'melt the solder; but to heat the work until the solder will flow when applied to the work.

3. Keep the soldering iron clean. Design. the tip 'to fit actually against the work to get the quickest possible heat transfer from the iron to thw work.

4: Investigate different methods available for doing the work, i.e., hotter electric irons, gas-operated irons, high frequency, and carbon resistance soldering tools.

5. Design your joints to have 0.003-to 0.005-inch solder thickness. and so' that the two parts overlap each other. Lap- or scam-type joints are better than butt-type joints. Have the solder fill the seam completely. Heavy fillets add little strength to the joints and are a waste of solder.

6. Don't hand a substitute solder, a flux, and a soldering job to a workman and expect a perfect job' the first time. Give him a chance to get the "feel"' of the new material Don't give up a substitute "solder after one unsuccessful trial--chances are your technique is not what it should be for that particular solder.

'It is important to remember that the object of using low-tin solders is to save tin. Obviously no savings is made, and needless expense and trouble are encountered, if so much more low-tin solder is used for a given joint that the actual tin present is as 'much, or more than when using a highcr tin solder. If calculations after thorough trial show that no saving of tin is being made, or a loss results, use of the substitute solder should be discarded.. Soldering technique improves with experience however, and if early results indicate that the use of a low-tin solder does not actually use more tin, the chances are good that a marked economy will develop with continued use.

In all industries there are a few companies with research organizations or enterprising individuals who will try out new ideas or methods or materials. Those who have worked with the low-tin and tin-free solders and have made them work are almost always glad to share their knowledge. Where trouble in soldering with substitute solders is encountered, therefore, it is an excellent plan to do some experimental work first to find the difficulties and advantages, then discuss the work with someone who is successfully doing a similar soldering job.

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TABLE 4. SOFT SOLDERS, A.S T.M. EMERGENCY SPECIFICATIONS[1]

Nominal Composition, %.					Solidus		Liquidus	
Tin	Antimony	Lead	Bismuth	Silver	°F.	°C.	°F.	°C.
30	0 to 0.4	Remainder	-	-	361	183	494	257
28	1.5 to 2.0	"	-	-	361	183	484	251
25	0 to 0.4	"	-	-	361	183	511	266
25	1.25 to 1.75	"	-	-	361	183	502	261
20	0 to 0.4	"	-	-	361	183	525	274
20	1.25 to 1.75	"	-	-	361	183	518	270
15	0 to 0.4	"	-	-	361	183	543	284
15	0.4 to 2.75	"	-	-	361	183	532-541	278-283
20	0 to 0.5	"	0 to 0.75	1.25	356	180	518	270
(20	0 to 0.5	"	5[2]	1.25	333	167	486	252)
15	0 to 0.5	"	0 to 0.75	1.25	358	181	532	278
(15	0 to 0.5	"	5[2]	1.25	333	167	503	262)
10	0 to 0.5	"	0 to 0.75	1.50	352	178	554	290
[illegible] to	0 to 0.5	"	-	2.50	579	304	579	304
0.65	0 to 0.5	"	-	0.25	579	304	608	320
0.85								

(1) These solders are the same as the SAE emergency solders 3 to 6, A and B, and E-01 to E-08 as listed in the 1943 SAE Handbook.

(2) The solders containing 5% bismuth, E-02 and E-04, have been removed from the list of SAE emergency solders.

RESTRICTED

RESTRICTED

TABLE 5. FLUXES

Flux	Characteristics	Use
Rosin	Noncorrosive, nonconducting, nonhygroscopic	Electrical
Tallow	Very mildly corrosive	Lead, brass, clean copper
Olive oil or Gallipoli oil	Very mildly corrosive	Pewter, block tin
Stearic acid	Mildly corrosive, almost nonconductive	Electrical, lead
Aniline phosphate or Aniline chloride	Mildly corrosive Almost nonconductive	Electrical
Lactic acid Pthalic acid Phosphoric acid Mixed with tallow, resin, etc.	Mildly corrosive Slightly conductive	Electrical
Zinc chloride	Corrosive	Iron, steel zinc, copper, brass, bronze, terne, and lead plate
Zinc chloride and HCl	Corrosive	Stainless steel, nickel, and Monel
Zinc chloride + HF	Corrosive	Brasses and bronzes containing aluminum, silicon, and manganese
Numerous proprietary pastes usually containing zinc chloride	Corrosive	
Zinc chloride and ammonium chloride	Corrosive	Iron, zinc, copper, brass, bronze
Dilute hydrochloric acid	Corrosive	Dirty zinc
Fused salts of zinc chloride and ammonium chloride	Corrosive	On dip pots

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