

PRINTING METALS



FRY'S

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INTRODUCTION

Printing Metals was first published in 1936 and immediately became the standard book on the subject. A major revision was made in 1956, and minor alterations in 1959. The present edition includes some further additions and alterations to keep abreast of modern techniques and machines, while maintaining the design of the original work.

Our aim has been to present an outline of the characteristics and working properties of Printing Alloys in a simple and brief form which will provide sufficient understanding of the use of these alloys in a printing works. For those who wish to study the subject further, appendixes dealing with the metallurgy of Printing Metals and other details have been included at the end of the book.

Good Printing Metal, properly used, will produce fine printed matter, and, if it is well cared for, will continue to give excellent results at a very small cost per job. It is the hope of the authors that this book will assist users of metals to obtain quality of reproduction and economy in cost.

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NOTE

Celsius Temperature Scale

IN previous editions temperatures have been expressed in the Fahrenheit scale with only passing reference to degrees Celsius, frequently called Centigrade. Over the years manufacturers of machinery and equipment have increasingly incorporated temperature controls using the Celsius scale and we have decided in this edition to include °C alongside °F in all the tables and graphs. To help the reader with temperatures appearing in the text we have provided below a list of all temperatures mentioned in °F alongside their conversions to °C.

°F	°C	°F	°C
-5	-20.5	567	297
32	0	600	315.5
120	49	621	327
166	74.5	629	331.5
250	121	646	341
300	149	650	343.5
325	163	700	371
440	232	720	382
449	232	730	388
463	239.5	750	399
486	252	787	419.5
503	261.5	797	425
518	270	950	510
520	271	1,000	538
530	276.5	1,167	630.5
550	288	1,474	801
560	293		

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HISTORICAL

THE use of metallic alloys in the art of printing is of ancient origin. It involved a considerable amount of experimental concentration and work, and great credit is due to the pioneer craftsmen who in the absence of definite scientific information assisted in laying the foundation of an industry which is so important a factor in our present civilization.

The first type metals. After the passing of type carved from birch and similar pieces of wood, the type-maker conceived the idea of using metal. The art of casting soft metals in engraved moulds of bronze or iron was already well known. The earliest known account of the art of type casting published in 1540 describes the use of the tin-rich alloys of the pewterer. But this was nearly a hundred years after the invention of movable type and it seems certain that elsewhere the less expensive metal—lead—was becoming established for the purpose.

Pure lead naturally proved too soft; it would not withstand the pressure and wear of the printing operation and the body was unable to keep its form; also the race of the type lacked sharpness and definition.

The hardening of lead by alloying it with tin was known but tin was always expensive and further the alloys of lead and tin still failed as castings to give a perfect type face.

The addition of antimony in varying proportions was found to confer upon the alloy the required properties—hardness, resistance to wear and to distortion under

pressure—and in addition it improved the sharpness of reproduction so that the type as cast had a good face and body. But antimony, although less expensive than tin, was not easy to obtain. The ore called stibnite, a natural sulphide of antimony, was fairly well known as it had many other applications in the arts, but metallic antimony was not a commonly known metal.

The story of the means adopted by the early type founders to produce their alloys is a good illustration of their ingenuity. It had been shown by the alchemists that when antimony sulphide ore was heated strongly with pieces of scrap iron, the metallic antimony was released and sulphide of iron produced as a by-product. The type founder, therefore, placed in his pot or crucible metallic lead and tin, and also some powdered antimony sulphide together with some iron horseshoe nails, which were erroneously supposed to be better than any other form of iron scrap. The whole was made red hot, and in due time an alloy of lead, tin, and antimony was obtained, the slag and sulphide rejected, and the alloy diluted with more lead as might be found necessary.

Development of the industry. The production of type-metal alloys became in later years an established industry, the constituent metals being available in a high degree of purity, until at the present time a range of various grades of metals is available for use in all the departments of the printing craft, the proportions of tin, antimony, and lead varying in accordance with the specific purpose required, the cost factor being necessarily an important one.

The standardization of quality, uniformity, and relia-

bility is an achievement of recent years. A survey of the metals in general use in 1912 showed wide differences in composition and the general standard was low, as is shown in the following list of assays of the standard grades of several manufacturers at that time.

Standards of 1912

	<i>Tin</i>	<i>Antimony</i>	<i>Lead</i>
Linotype Metal	%	%	
No. 1	trace	13.26	balance
2	3.74	11.81	"
3	1.08	10.89	"
4	1.71	11.98	"
Monotype Metal			
No. 1	4.32	21.17	"
2	4.92	18.82	"
3	2.64	10.93	"
4	6.28	16.49	"
5	7.44	17.23	"
Stereotype Metal			
No. 1	trace	17.06	"
2	5.88	13.58	"
3	1.23	13.75	"
4	3.72	16.60	"

Comparison with the present-day standards given later in this book will show the improvement which has taken place, in particular the higher proportions of tin which are now generally used. Research work indicated the 'theoretical' value of the present alloys; the printer's experience confirmed it.

REQUIREMENTS AND PROPERTIES OF PRINTING METALS

THERE are certain essential requirements for alloys to be used in the manufacture of type.

1. The alloy should melt cleanly and at a low temperature.
2. The alloy should cast easily and there should be no tendency to clog small apertures in mouthpieces and nozzles.
3. The alloy should give a sharp casting correct in form and dimension when cold.
4. Type cast from the metal should be sufficiently hard and strong to withstand distortion under pressure and to resist abrasion during the process of printing.

The only range of alloys which satisfies these requirements and at the same time is reasonable in cost is that founded on lead as the basis, with additions of tin and antimony adjusted to the purpose for which the metal is required.

Lead melts at 621° F. It is exceptionally malleable and ductile but soft and weak and does not give sharp definition when cast against a mould.

Antimony melts at 1,167° F. It is a brittle metal, crystalline in appearance. When alloyed with lead, antimony performs two outstanding services. Firstly, it improves the quality of reproduction so that sharp clear letters are obtained. Secondly, it substantially hardens and strengthens the metal.

Tin melts at 449° F. It is a soft and ductile metal but is tougher than lead. It hardens lead, but unlike antimony it does not cause brittleness. In consequence, tin produces a more wear-resistant alloy. Tin also makes the metal more fluid and mobile when molten and gives a finer face to the type.

Printing alloys generally contain 3-10% tin, 11-16% antimony, balance lead, but for certain uses may contain up to about 20% tin and 30% antimony. Considered as a group these alloys have distinctive properties which are important to the printer.

Melting at a low temperature. The alloys ordinarily used for slugs, 'Monotype' composition, and stereotype plates are all molten at temperatures not exceeding 550° F. This is well below the melting-points of most of the other metals in common use (Table I, p. 6).

Much benefit is derived because the alloys can be cast at a low temperature. Cooling of the type is rapid, so permitting high rates of casting. Wear on the matrices and distortion of the mould are reduced to a minimum. Last but not least, pleasant working conditions can be maintained in composing room or foundry.

Melting temperatures of the alloys. In the type-metal range, the lowest melting-point is secured with an antimony content of 12%. As the antimony content is increased beyond 12% the melting-point rises. This question is dealt with in detail in the next chapter.

Clean melting. Many metals, for example zinc, form a large amount of dross when they are melted, especially if there is agitation such as occurs in the pot of a casting

machine. The tin-antimony-lead alloys, however, produce comparatively little dross, a valuable economic advantage since printing metals are melted over and over again.

Some metals when molten attack iron and steel. Thus aluminium corrodes iron pots in which it is melted. Pure tin forms a surface alloy on steel and a similar effect is sometimes obtained with lead alloys, rich in tin, but as a rule, long life can be expected from the working parts of machines which come into contact with molten printing metals.

TABLE I
Melting-points of Common Metals

	<i>Melting-point</i>	
	<i>°F.</i>	<i>°C.</i>
Aluminium	1,220	660
Antimony	1,167	630
Arsenic	1,139*	615*
Bismuth	520	271
Cadmium	610	321
Chromium	3,430	1,890
Copper	1,981	1,083
Gold	1,945	1,063
Iron	2,802	1,539
Lead	621	327
Magnesium	1,202	650
Mercury	-38	-39
Nickel	2,651	1,455
Silver	1,761	960
Tin	449	232
Titanium	3,308	1,820
Zinc	787	419

* Arsenic sublimates at this temperature

Reproduction of detail. Sharpness of reproduction

depends on the free flowing qualities of printing alloys. Not only is the molten metal fluid; the surface also is mobile and under the pressure of casting, penetration into the finest detail can occur.

The importance of these attributes becomes manifest if the metal is contaminated with zinc; a tough skin then forms whenever a fresh surface is exposed and this so holds the metal back that penetration is impaired. Corners which should be sharp are rounded; outlines are generally fuzzy and the quality of reproduction is ruined.

TABLE II
Shrinkage of Metals during Solidification

	<i>%</i>
Electro backing metal shrinks by approx.	2.6
Slug casting metal	2.3
Monotype metal	2.0
Lead	3.4
Tin	2.8
Antimony expands	0.9

It should be added that further loss of volume by contraction takes place during cooling to room temperature after solidification has occurred.

It was once thought that sharpness of reproduction results from the expansion of the metal as it solidifies. Pure antimony has the unusual property of expanding on solidification, but the commonly used printing metals all shrink on solidification. Measurements of volume during cooling show a contraction of about 2% when the metal changes from the liquid to the solid state. The shrinkage is less for printing metals, particularly those of high antimony content, than for most other alloys in industrial use, but it does occur.

Good melting and casting properties explain the universal use of tin-antimony-lead alloys as printing metals. The alloys within the range of printing metals differ amongst themselves, however, more particularly in melting temperature and in hardness. These are features which must be considered when a precise composition is to be chosen for a given purpose.

Hardness and resistance to wear. Printing metals in service are subjected to both pressure and abrasion. To resist these, the type must be sufficiently hard and solid.

With reservations, it can be said that greater hardness will bring improved wear resistance. The hardness of an alloy can be increased by raising the antimony content, preferably with a simultaneous increase in the tin content.

The performance of type in service, however, depends not only on the properties of the metal, but also on the soundness of the type.

While antimony additions harden the metal, each addition (beyond 12%) raises the melting-point and makes it more difficult to maintain the production of solid type.

A balance must be struck between these two opposing factors—hardness and ease of casting. Where the balance comes depends on the purpose for which the metal is required. A few examples from practice may make the point clearer.

Slug-casting. The conditions on slug-casting machines demand a metal which will freeze quickly over a narrow range of temperature. The alloys with the lowest melting-points are therefore used for this purpose, i.e. those with 11–12% of antimony with which it is usual to combine

3–4% of tin. These alloys are necessarily softer than other printing metals.

'Monotype' composition. Type with improved surface hardness and wear resistance is obtained by using higher tin and antimony contents; 6–10% tin with 15–16% antimony is commonly used for 'Monotype' composition. Such alloys can be cast on the machine at high speeds in everyday conditions, although the melting-point is somewhat higher than for slug metal.

Case type. Still harder metals such as are used for case type with up to 27% of antimony and up to 14% of tin need special care in casting because of the high melting temperatures.

Stereotyping. High casting temperatures are not permissible in stereotyping owing to the limitations imposed by the nature of the flog. Antimony contents of 14–15%, with tin contents of 6–10%, give the best wear resistance with speed and reliability of casting.

MELTING AND FREEZING OF PRINTING METALS

THE necessary balance of properties required by the printer can only be obtained by the use of *an alloy*.

Pure metals find application for a variety of purposes—thus pure copper is used for electric wiring, lead for atomic shielding, aluminium for power cables, but there are only about twenty metals in common use and the range of properties which they offer is clearly restricted for modern requirements. On the other hand, a wide variety of properties can be secured by mixing two, three, or more different metals together. Many hundreds of such alloys have been developed each offering its special combination of properties.

Alloys are usually made by melting the constituent metals together and then pouring the mixture into a mould. It would be wrong to regard an alloy as a simple mixture however, since its properties may be very different from those of the pure metals. The alloy may for example be many times stronger than its constituent metals, as bronze is stronger than the copper and tin from which it is made.

An alloy for casting type must, above all, melt easily and solidify to give a faithful reproduction of the mould. The changes which occur when the metal passes from solid to liquid and vice versa are therefore of fundamental importance.

Knowledge of the changes not only helps towards an

understanding of the constitution of the alloys; it is of practical value to the user.

Melting of a pure metal. A *pure metal* melts at a fixed and sharp temperature which is called the melting-point. On cooling from the liquid condition, it solidifies at the same temperature which can equally well be called the freezing-point of the metal.

With a pure metal, then, there is a well-defined temperature below which the metal is always completely solid, above which it is completely molten. Certain special alloys behave in similar fashion but as a general rule an alloy melts and solidifies over a range of temperatures; it commences to melt at one temperature but it is not completely molten until a higher temperature is reached.

Thus the term 'melting-point' is not strictly applicable. The temperature at which an alloy becomes completely liquid when it is heated, and at which it starts to solidify on cooling, is called the 'liquidus temperature'. The temperature at which the alloy becomes completely solid is called the 'solidus temperature'.

Metals in the liquid state. The majority of the printing metal alloys are completely molten at temperatures above 550° F. How can alloys be molten at such low temperatures when they contain antimony which melts only at 1,167° F.?

The simplest way of answering this question is to consider alloys as solutions. The antimony can be regarded as being dissolved in molten lead, the liquid then being quite homogeneous.

A familiar example may make this clearer. Stir a tea-

spoonful of common salt into a cup of water. The crystals of salt disappear. Sometimes they are said to melt but more correctly they dissolve. The result is a homogeneous fluid, a solution. The most powerful microscope fails to reveal any solid particle in a drop of the fluid.

This result is achieved without any application of heat, yet the melting-point of salt is $1,474^{\circ}$ F. Just as salt, which has a high melting-point, dissolves in water to give a uniform liquid, so solid antimony will dissolve in molten lead and will remain dissolved so long as a suitable temperature is maintained.

An additional effect of salt in water is to lower the freezing-point. Use is made of this in winter when salt is thrown on icy pavements. Even though the temperature is still below 32° F., the ice melts because the mixture of ice and salt has a much lower freezing-point.¹ Later it will be seen that, within limits, antimony added to lead lowers the freezing-point of the metal.

Separation of crystals. The analogy between an alloy and a solution of salt may be pressed still further. If more and more salt is added to the solution, there will come a point when the solution is saturated and the addition of even a single crystal will result in that crystal remaining undissolved. If now the solution is heated it will be found that a further quantity of salt can be dissolved but there will again come a point at which the solution is saturated.

Now allow the hot saturated solution to cool down.

¹ A mixture of ice with 23.6% of salt melts at -5° F., 37° below the freezing-point of water. This is called a eutectic mixture; no mixture of ice and salt has a lower melting-point.

The excess salt will separate from the solution in the form of crystals.

Similarly, a molten alloy is a solution which becomes saturated when it is cooled to the liquidus temperature. Further extraction of heat causes solid crystals to separate from the solution.

The process of solidification, therefore, is in effect a process of crystallization. When a metal is cast it may solidify in a fraction of a second but in that short time the characteristic crystal structure is formed.

Crystalline nature of metal. It is easy to see that some metals are crystalline. Antimony is a good example; the crystals of which it is composed show both on the surface of the metal and in the fracture.

Other metals like iron, copper, tin, and lead might not seem to be crystalline because they are tough and ductile, whereas crystals are normally thought of as being brittle and easily crushed. Nevertheless, these metals also are composed of crystals (Fig. 2). As a rule the crystals are so small that they can only be observed satisfactorily under the microscope when the surface of the metal has been specially prepared.¹

Crystallization of alloys. A pure metal is composed of one kind of crystal only. In an alloy there may be two, three, or more crystal components.

The sequence of crystallization in an alloy may be quite complicated. It will be simplest to begin with alloys containing only two metals and to find out how the solidification process is affected when the proportions of the constituent metals are altered.

¹ See Appendix II.

Alloys of antimony and lead. Consider first the behaviour of a potful of pure lead which has been melted

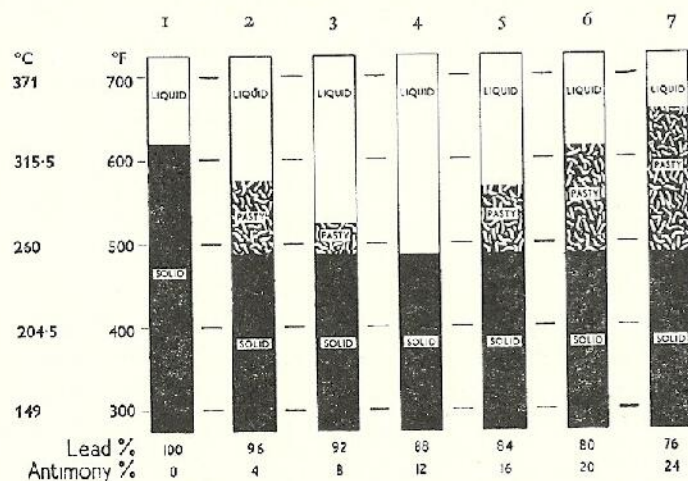


FIG. 1. Solidification temperatures of some lead-antimony alloys.

1. Pure lead solidifies completely at the single temperature of 621° F.
2. The alloy 96% lead, 4% antimony remains liquid below this temperature. Solidification starts at 576° F, but the temperature continues to fall to 486° F, when it remains steady until the last fraction has set.
3. The alloy 92% lead, 8% antimony has a still lower liquidus temperature and a shorter freezing range but the temperature of final solidification is the same at 486° F.
4. The alloy 88% lead, 12% antimony solidifies at the single constant temperature of 486° F. This is the eutectic alloy.
5. Alloys with more than 12% of antimony again solidify over a range of temperature. The alloy with 16% antimony commences to solidify at 567° F, but the temperature of final solidification is the same at 486° F.
- 6 and 7. As the antimony content is increased the liquidus temperature becomes progressively higher although in each case the metal finally solidifies at 486° F.

and allowed to cool. As long as the metal is still molten the temperature falls regularly. Then at 621° F. the cooling

is arrested and the temperature remains constant. A glance at the pot shows that there is solid metal on the sides: in fact crystals of lead are forming and growing. The temperature remains at 621° F. until the whole of the lead has solidified. Then, and only then does it start to fall again.

When small amounts of antimony are alloyed with lead several important differences are noticed:

1. The liquidus temperature, at which the alloy commences to solidify, is lower than the freezing-point of lead.
2. While the first part of the alloy is solidifying, the temperature continues to fall. Thus the alloy solidifies not at a single temperature but over a range of temperatures; this is called the freezing or 'pasty' range.
3. The final portion of the alloy solidifies while the temperature remains steady at 486° F.

As more antimony is added, the liquidus temperature is lowered still further but the alloys solidify at the same temperature of 486°. Thus the freezing range becomes shorter and shorter until a composition is reached—12% antimony, 88% lead, which solidifies sharply at the single temperature of 486° F. This is the only alloy containing both antimony and lead which solidifies at one temperature.

Beyond this point, each addition of antimony raises the liquidus temperature again. These alloys with more than 12% antimony also solidify over a range of temperature; all finally solidify at the same constant temperature of 486° F.

The last two features have great significance in practice.

Alloy containing 12% antimony, 88% lead: the 'Eutectic' alloy. This has the lowest melting-point of all the alloys of antimony and lead. It freezes at one temperature only, thus behaving somewhat like a pure metal in having no freezing range.

Such an alloy is known as a 'eutectic', which means easy melting.

Alloys containing more than 12% of antimony. These solidify over a range of temperatures. The higher the antimony content, the higher is the temperature at which solidification commences, and the longer is the freezing range.

The alloys contain antimony in excess of the eutectic proportion. The excess antimony crystallizes out in the form of fine particles during the initial stage of the solidification process. Thus when a molten alloy containing 16% antimony, 84% lead is cooled, solid crystals of antimony, distributed throughout the metal, form and grow throughout the mass while the temperature is falling from 567° to 486° F.

The formation of crystals withdraws antimony from the liquid metal and the latter becomes the poorer in antimony. By the time the temperature has fallen to 486° so much antimony has separated out that the residual liquid contains only 12% antimony (i.e. the composition of the eutectic) and the temperature then remains constant while this last fraction of the alloy solidifies.

Alloys containing less than 12% of antimony. These alloys behave similarly in solidifying over a range of temperatures but since it is lead which is in excess of the eutectic composition, crystals of lead deposit in the initial

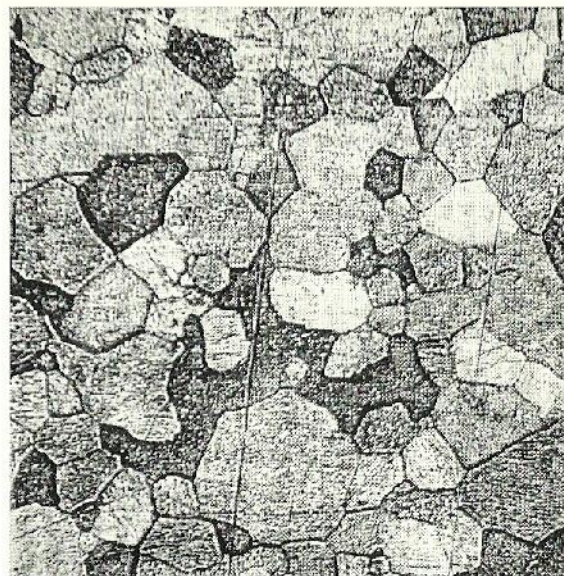


FIG. 2. Photo-micrograph of a pure metal. Tin

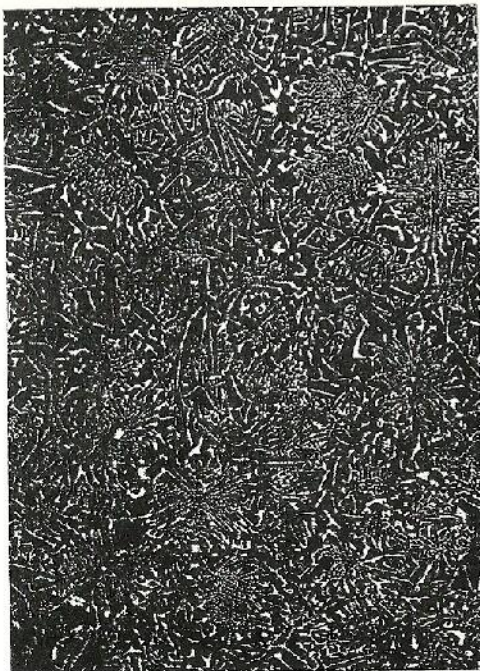


FIG. 3. EUTECTIC ALLOY

4% tin
12% antimony
84% lead

This 'alloy' has fixed composition and melting point. Note the characteristic finely laminated structure

Magnification: 250 times



FIG. 4. SLUG-CASTING METAL

3% tin
11% antimony
86% lead

This alloy contains more lead than the eutectic. The excess separates as crystals (dark, rounded) in the first stage of the solidification process. The groundmass is the eutectic constituent

Magnification: 100 times

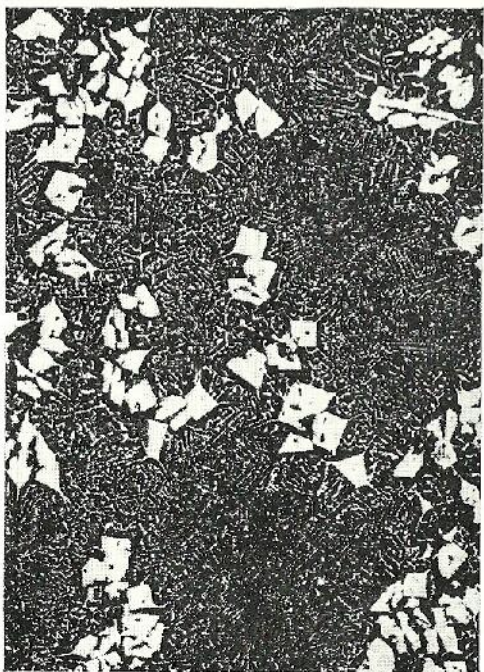


FIG. 5. STEREOTYPE METAL

7% tin
15% antimony
78% lead

Tin and antimony are above the eutectic proportions. The excess forms the cubic tin-antimony crystals (white)

Magnification: 100 times

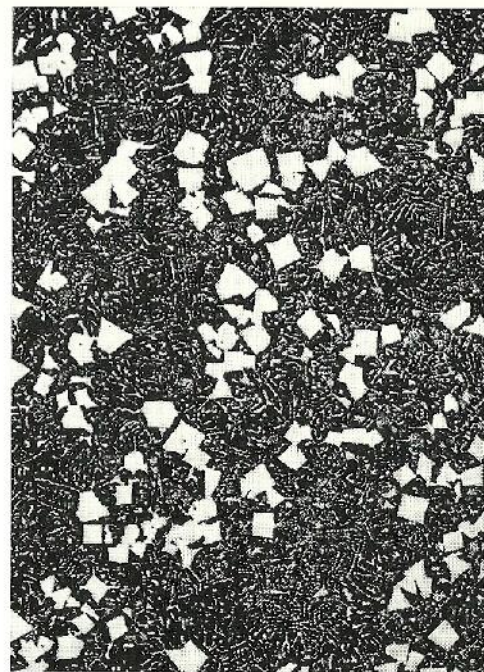


FIG. 6. MONOTYPE METAL

10% tin
16% antimony
74% lead

Compare with Fig. 5. The higher tin and antimony contents here result in an increased proportion of tin-antimony crystals

Magnification: 100 times

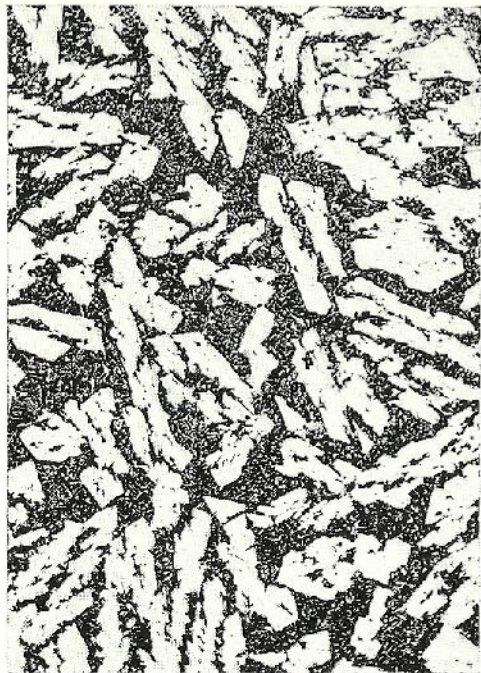


FIG. 7. TYPE METAL

18% tin
28% antimony
54% lead

This rich alloy containing a high proportion of tin-antimony crystals has excellent resistance to wear. Note that the eutectic matrix is present in all the alloys

Magnification: 100 times



FIG. 8. STEREO TYPE METAL

5% tin
15% antimony
80% lead

This alloy has a low ratio of tin to antimony content in comparison with the alloys in Figs. 5 and 6. The crystals here are not so hard or so resistant to wear

Magnification: 100 times

stage of solidification. As a result, the liquid metal becomes enriched in antimony. At 486° the excess lead will have crystallized out; the liquid metal will then contain 12% of antimony and will solidify before the temperature falls further.

Thus all the alloys finally solidify at the same temperature of 486° because all contain a proportion of the eutectic as a constituent. Alloys containing an excess of antimony are seen under the microscope to consist of finely distributed crystals of antimony embedded in a groundmass of eutectic alloy.

Tin a modifying metal. For a simple picture, it is possible to consider printing metals as alloys of antimony and lead, modified by additions of tin.¹

The important modifications are:

1. Some of the tin enters the eutectic, which then has the approximate composition 4% tin, 12% antimony, 84% lead, and solidifies sharply at 463° F. All normal type metals contain a proportion of eutectic and all as a result become finally solid at 463° .
2. When the alloy contains more than 12% of antimony, the excess separates during the first stage of solidification in the form of crystals containing both tin and antimony. These crystals are much harder and more wear resistant than crystals of pure antimony, such as separate from alloys containing lead and antimony only.

¹ This treatment necessarily omits much detail which is important metallurgically. The reader who is interested in following the matter further is referred to Appendix I.

The eutectic in printing alloys. The eutectic alloy containing 4% tin, 12% antimony, 84% lead, has the lowest melting-point of any alloy in the printing metal range. Although the eutectic has a fixed composition and fixed melting-point the microscope shows it to be a mixture of crystalline constituents (Fig. 3). In the freezing of the alloy, the constituents are deposited side by side, producing the characteristic laminated structure. The dark constituent is substantially pure lead; the light constituents are composed of tin and antimony.

The eutectic is comparatively soft. For improved wear resistance in direct printing, a harder metal is desirable. This requirement is met by increasing the tin and antimony contents beyond the eutectic proportions.

Printing alloys with more than 12% antimony. Additions of antimony beyond 12% progressively raise the liquidus temperature. The alloys thus made solidify over a range of temperature but all finally become solid at the eutectic temperature, which, when tin is present, is 463°.

The composition 7% tin, 15% antimony, 78% lead, may be taken to illustrate the behaviour of metals for 'Monotype' composition and for stereo plates.

A potful of this alloy properly melted and at a temperature of say 650° F., is completely molten and uniform. Now the pot is allowed to cool. Nothing visibly changes until the temperature reaches 503° when here and there throughout the metal, solid particles form, microscopically small. If the metal is stirred, it will look as if it contains 'grit'. As cooling proceeds, these particles become larger and more numerous; the metal thickens to a pasty consistency.

The particles are in reality tin-antimony crystals. As they grow, the metal which is still liquid becomes progressively poorer in tin and antimony. By the time the temperature reaches 463° the excess tin-antimony has crystallized out, leaving liquid metal of eutectic composition. The temperature then remains steady while the eutectic solidifies around the crystals.

The 'freezing range' of this alloy extends from 503° to 463°, i.e. 40°.

Structure and wear resistance. The structure of this alloy (Fig. 5) shows tin antimony crystals surrounded by eutectic. The eutectic provides a tough though relatively soft groundmass; the hard crystals distributed throughout the metal strengthen it and at the surface offer improved resistance to wear and abrasion.

The picture is similar to a mass of pitch with granite chips embedded in it.

If the alloy has only a low tin content, the crystals which separate also contain little tin and consist principally of antimony. Raising the proportion of tin improves the hardness and wear resistance of the crystals and consequently of the alloy as a whole.

Maximum advantage is secured if the alloy contains sufficient tin to combine with the excess antimony to form the compound of tin and antimony. This compound contains 50% tin, 50% antimony, and is much harder than pure antimony.

The presence of the compound accounts for the superior wear resistance of alloys having a balanced proportion of tin to antimony. When the antimony content is 15%, the presence of 7% of tin or over ensures that the crystals

The eutectic in printing alloys. The eutectic alloy containing 4% tin, 12% antimony, 84% lead, has the lowest melting-point of any alloy in the printing metal range. Although the eutectic has a fixed composition and fixed melting-point the microscope shows it to be a mixture of crystalline constituents (Fig. 3). In the freezing of the alloy, the constituents are deposited side by side, producing the characteristic laminated structure. The dark constituent is substantially pure lead; the light constituents are composed of tin and antimony.

The eutectic is comparatively soft. For improved wear resistance in direct printing, a harder metal is desirable. This requirement is met by increasing the tin and antimony contents beyond the eutectic proportions.

Printing alloys with more than 12% antimony. Additions of antimony beyond 12% progressively raise the liquidus temperature. The alloys thus made solidify over a range of temperature but all finally become solid at the eutectic temperature, which, when tin is present, is 463°.

The composition 7% tin, 15% antimony, 78% lead, may be taken to illustrate the behaviour of metals for 'Monotype' composition and for stereo plates.

A potful of this alloy properly melted and at a temperature of say 650° F., is completely molten and uniform. Now the pot is allowed to cool. Nothing visibly changes until the temperature reaches 503° when here and there throughout the metal, solid particles form, microscopically small. If the metal is stirred, it will look as if it contains 'grit'. As cooling proceeds, these particles become larger and more numerous; the metal thickens to a pasty consistency.

The particles are in reality tin-antimony crystals. As they grow, the metal which is still liquid becomes progressively poorer in tin and antimony. By the time the temperature reaches 463° the excess tin-antimony has crystallized out, leaving liquid metal of eutectic composition. The temperature then remains steady while the eutectic solidifies around the crystals.

The 'freezing range' of this alloy extends from 503° to 463°, i.e. 40°.

Structure and wear resistance. The structure of this alloy (Fig. 5) shows tin antimony crystals surrounded by eutectic. The eutectic provides a tough though relatively soft groundmass; the hard crystals distributed throughout the metal strengthen it and at the surface offer improved resistance to wear and abrasion.

The picture is similar to a mass of pitch with granite chips embedded in it.

If the alloy has only a low tin content, the crystals which separate also contain little tin and consist principally of antimony. Raising the proportion of tin improves the hardness and wear resistance of the crystals and consequently of the alloy as a whole.

Maximum advantage is secured if the alloy contains sufficient tin to combine with the excess antimony to form the compound of tin and antimony. This compound contains 50% tin, 50% antimony, and is much harder than pure antimony.

The presence of the compound accounts for the superior wear resistance of alloys having a balanced proportion of tin to antimony. When the antimony content is 15%, the presence of 7% of tin or over ensures that the crystals

consist wholly of tin-antimony compound; with 20% of antimony, more than 10% of tin is necessary to achieve the same result.

The hardness and wear resistance of type metals depend firstly on the hardness of the crystals which is at a maximum when there is a balanced ratio of tin to antimony, and secondly on the proportion of crystals present which is increased by raising the tin and antimony contents together.

Thus founder's type is rich in both tin and antimony and therefore contains a high proportion of the hard crystals of tin-antimony compound.

Alloys of this kind have comparatively high melting temperatures. For example the hard metal 18% tin, 28% antimony, 54% lead, commences to freeze at 629° F. As the eutectic portion solidifies, again at 463° F., the solidification range is 166° compared with only 40° for the alloy just considered.

These alloys must be cast at a high temperature but the type still has to cool to 463° F. before it can be ejected from the mould. Longer time must be allowed for the type to solidify in the mould, by reducing the rate of casting.

Additionally, these alloys contain so much tin-antimony constituent that extra care must be taken during casting to prevent chilling in the pot and metal passages.

STRUCTURE OF ALLOYS IN RELATION TO PRACTICAL HANDLING

It is sometimes said that type metal is a mixture of tin, antimony, and lead, and that if the liquid metal is allowed to stand for some time the constituent metals will separate into three layers. It will be clear from the 1st chapter that this statement is not true. For each composition there is a definite temperature above which the alloy is molten. If the alloy has been properly melted, then it will remain homogeneous and completely liquid so long as the metal, or any part of it, does not cool below that temperature.

Practical evidence of this is provided by hand-by stereo pots which, thermostatically controlled at suitable temperature, have remained quite molten and uniform for years on end.

It is when the metal passes through the solidification range that problems may arise. In practice these problems are encountered only with alloys containing over 12% of antimony; they do not arise in alloys used for slug casting, where the percentage of antimony is 12% or less.

Indispensable to an understanding of the problems is the mental picture of what is going on inside the metal as it passes through this range. The picture is first of liquid metal which, on cooling, remains homogeneous until the temperature falls below the liquidus. Then, myriads of tiny crystals, forming throughout the mass and growing, so that the metal becomes first 'gritty' and then thickens

with continued cooling until it becomes quite pasty. Finally, the remaining liquid solidifying around the crystals.

It is the intermediate stage which is so important in melting and casting practice, when the metal is part solid, part liquid.

Growth of the crystals. The size of the crystals which grow as the liquid metal cools through the solidification range depends on the rate of cooling. If cooling is very slow, there is plenty of time for the crystals to grow, and the final metal will contain large crystals. If cooling is rapid, time for growth is restricted and the result is a large number of extremely small crystals. This is illustrated by the photomicrographs in Figs. 9-11 comparing the microstructure of metals cooled at different speeds.

The size of the crystals will be better appreciated if it is realized that the area of metal surface photographed is less than one-fiftieth of an inch square.

A rough calculation based on Fig. 11 puts the number of tin-antimony crystals in a single 10 point stamp of Monotype at approximately 100 million!

Coarse crystals are dangerous. When Monotype and Stereotype metals are heated, the eutectic liquifies first and then, as the temperature rises, the tin-antimony crystals dissolve in the molten metal. Clearly, the process of dissolving the crystals in the pot of a composing machine will be easier if they are fine and evenly distributed, rather than coarse and aggregated together. (To dissolve salt in water, it is quicker first to crush the lumps to a fine powder.) There is always the possibility too that large crystals will remain undissolved and will act as grit, clogging the pump mechanism or the nozzle.

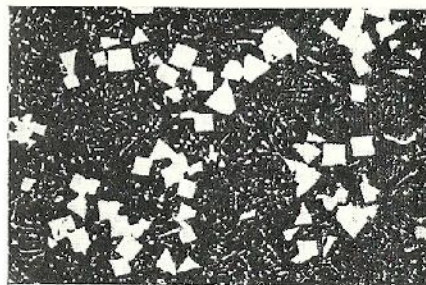


FIG. 9. Section cut through a slowly cooled ingot of stereo metal. The crystals have grown comparatively large

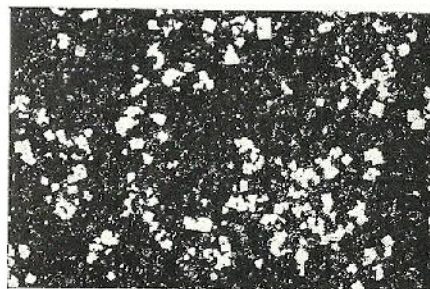


FIG. 10. Section from a flat stereo plate. Solidification was rapid and the crystals are correspondingly finer

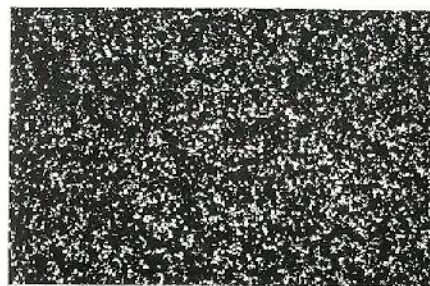


FIG. 11. Section through a stamp of Monotype. Solidification took only a fraction of a second. The tin-antimony crystals are minute, only about one ten-thousandth of an inch across

Effect of rate of cooling on structure of printing metal

Magnification for Figs. 9-11: 100 times

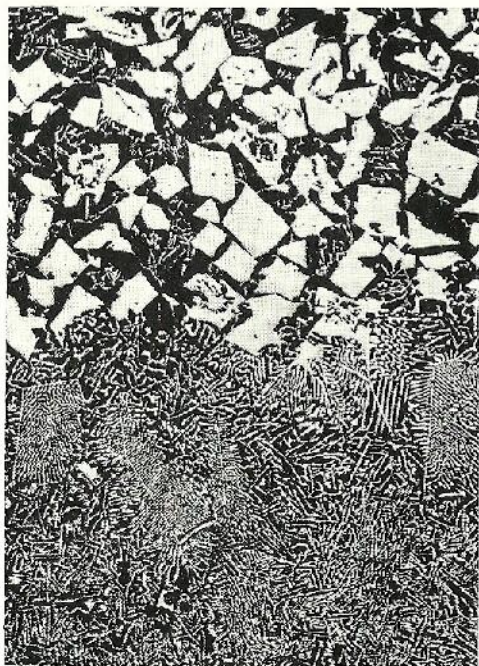


FIG. 12. Section through Monotype metal cooled very slowly. The tin-antimony crystals have segregated towards the surface

Ingots for composing machines should therefore have as fine a structure as possible. This is assured by pouring the metal at the correct temperature into cold moulds, so that solidification is rapid.

Segregation of crystals. As Monotype and Stereotype metals cool below the liquidus temperature, solid tin-antimony crystals form throughout the mass. The crystals are light in comparison with the liquid metal which is rich in lead. Consequently they tend to float to the surface. Thus, whenever an alloy of this kind is in the semi-molten condition there is a tendency for separation to occur; two layers are formed, the upper rich in tin-antimony crystals, the lower consisting of more leady metal.

If this effect is followed to its conclusion, and the metal is allowed to cool very slowly, all the tin-antimony crystals are concentrated in the upper layer while the lower layer consists entirely of eutectic (Fig. 12).

Rate of segregation. Type is normally cast so rapidly that the metal passes from liquid to solid very quickly. The light tin-antimony crystals have not time to float upwards before the freezing of the eutectic locks them in position. In type, therefore, the crystals are uniformly distributed. It is in the melting or remelting of metal that the danger of segregation may arise. Suppose for example that a pot of Monotype or Stereotype metal is accidentally cooled below the liquidus temperature. Since a large bulk of metal cools slowly, conditions are ideal for the formation and separation of very large crystals. The metal on the surface will have a pasty appearance, but to skim it off would be wasteful.

Segregation in machine pots. Solid crystals floating around in the pots of Monotype or Stereotype machines cause irregular working. To restore normal conditions, the metal must be reheated to the correct temperature and then thoroughly stirred to make sure that the large crystals are redissolved.

Segregation during melting. Segregation can also take place as Monotype and Stereotype metals are being melted; for if the temperature rises slowly, as soon as the eutectic is molten the crystals are free to float upwards. Quick melting is therefore always desirable, whether in the composing machine pots, stereotyping pots, or remelting pots.

Casting conditions in composing machines. In a composing machine the metal is pumped through a nozzle or mouthpiece into the mould. The pump must maintain pressure until the type has solidified, otherwise the foot will bleed. During this brief period the metal in the nozzle or mouthpiece is chilled.

With satisfactory working conditions, this metal remains fluid and is withdrawn by the return stroke of the pump. If chilling is excessive, however, the metal starts to solidify in the nozzle and throat passages; if the condition is not corrected a deposit builds up. The obstructed passages hamper the flow of metal to the mould and so cause hollow type and slugs. If the deposit continues to build up it will ultimately stop casting.

It will be clear that it is not sufficient to maintain metal in the pot just molten. A higher temperature must be maintained (*a*) to counteract chilling of the metal channels,

and (*b*) to reheat the metal sucked back by the pump in time for the next cast.

The fitting of thermostats as standard equipment has gone a long way towards maintaining trouble-free working simply because in normal circumstances undue chilling of the metal is prevented, but it can still happen. For example, at the commencement of the day the whole machine is cold and the stream of metal from the pump loses heat rapidly. Draughts blowing across the pot in winter, or several nuggets of cold metal added when the level has fallen too low, may so chill the metal that the smooth operation of the machine is upset.

Correct temperatures must be maintained not only in the pot but also throughout the casting system to keep the metal channels clear and thus permit the routine production of sound type.

THE RESISTANCE OF TYPE TO WEAR IN SERVICE

REMARKABLE service can be obtained from type in the best conditions—clean printing is still secured after many thousands of impressions and runs of several hundred thousand have been recorded.

Such results bear witness to the hard wearing qualities of the type but when comparisons are made of practical performance, many factors have to be taken into account. Those which influence the run itself, for example, the condition of the press, accuracy of make ready, effect of reprinting, nature of the paper, lie outside the present discussion. What will be considered is the wear resistance of the type as it is affected by the composition of the metal and by the presence of defects.

'Wear' is taken to cover any change in dimension of the type which affects clarity of printing. It may occur in several ways, but the essential requirement to combat any form of wear is that the type should combine hardness with solidity.

Hardness of printing metals: effect of antimony.

Antimony additions harden the metal but in excess of 12% raise the liquidus temperature. This is illustrated in the following table comparing alloys with constant tin content but increasing antimony content.

Tin %	Antimony %	Lead %	Completely liquid °F. °C.	Brinell Hardness No.
4	12	balance	463 239.5	22.0
4	16	"	531 277	22.5
4	20	"	601 316	24.0
4	24	"	646 341	26.2

Hardness of printing metals: effect of tin. Tin with antimony together as alloying elements produce a much greater hardening effect than antimony alone. Consider the following figures:

Tin %	Antimony %	Lead %	Completely liquid °F. °C.	Brinell Hardness No.
4	22	74	626 330	25
10	16	74	535 274	27

The two alloys contain the same proportion of lead. The first composition represents an attempt to obtain hardness through high antimony content. The second contains tin and antimony in balanced proportions; not only does it melt at a much lower temperature than the first and is therefore easier to cast, but, at the same time, it is distinctly harder.

A further advantage does not show in the figures. Alloys of high antimony content tend to be coarse and brittle; a balanced composition is much tougher and offers greater resistance to battering. Thus a judicious balance between the tin and antimony proportions gives the best combination of wear resistance with ease of melting and casting.

Solidity. If a casting is to be completely solid the metal should enter the mould in a slow stream and should not commence to solidify until all the air has had time to get away. In the pouring of flat stereotypes by hand these ideal conditions can be closely approached and the plates rarely contain much porosity in the body.

On machines for casting slugs, type, and plates however, the demand for high operating speeds necessitates rapid injection of metal into the mould and rapid solidi-

fication of the casting. The metal inevitably becomes mixed with air and solidifies before the air can escape, leaving voids in the casting.

Many hundreds of measurements have been made of the degree of porosity which occurs in practice. Type of the highest quality has contained 6-8% of voids; in routine production 10-20% of voids is common.

Clearly one aim must be to achieve the best possible degree of solidity. But it is still more important to ensure that such air bubbles as remain are located where they can do the least harm. So long as porosity is not close to the printing surface, some porosity in the body does not unduly matter.

In composing machines the metal is injected into the mould under pressure. On reaching the matrix the metal should remain fluid for a brief interval so that it can spread to form a smooth face and allow air to escape.

If the metal is cast at a low temperature, is chilled in casting, or cooled excessively in the mould, it sets almost instantaneously against the matrix. Evidence of this may be provided by chill marks or a frosty face, but even if the face appears perfect the metal just beneath will be porous due to air trapped by the rapid solidification of the metal. This is known as sub-surface porosity.

The porosity may take the form of large air bells in the characters or of a chain of small bubbles. Its effect will be noticed only when the type sinks under pressure or the face crumbles in use.

The porosity can be seen under the microscope if the type is sectioned and polished (Figs. 13-16). Type cast under the correct conditions has a solid face and even

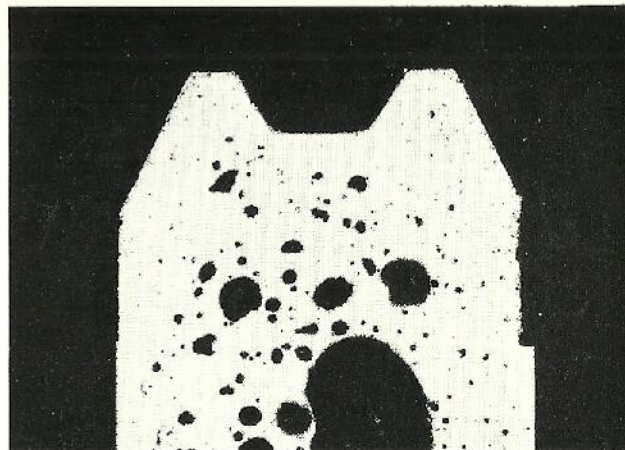


FIG. 13. Section through a stamp of Monotype. The character is solid and although there is porosity in the body, this type would give good service

Magnification: 25 times

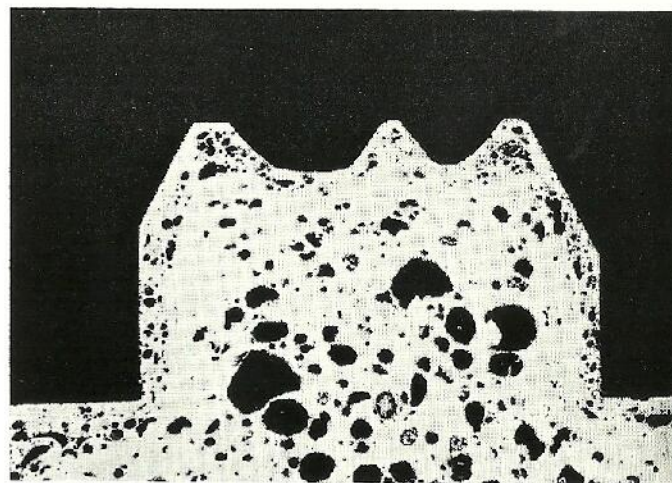


FIG. 14. Section through a stamp of Monotype. Note the small air bubbles just under the face. This sub-surface porosity is likely to cause the type face to sink under pressure

Magnification: 25 times

though there may be much entrapped air in the body, it will stand up well in service.

The metal passages in the composing machines must be clear. A partially impeded metal flow not only reduces the rate of entry into the mould but also will break up the jet into a spray causing poor face quality and entrapment of air.

For type to be solid, then, it is essential to deliver a full flow of fluid metal to the mould, and attention must constantly be given to the features in casting which affect the flow—correct temperature, plunger pressure and alignment to mould, clear metal passages and air grooves.

Wear in use: printing. Wear in printing has two separate causes. The direct pressure at the moment of impression may compress the type; there is no loss of metal but a reduction in height. To resist compression the type must be solid. In addition there is the abrasive action on the type, removing metal from the surface in contact with the paper and more particularly from the edges. To resist this the type should be as hard as possible.

Wear in use: moulding. When formes are moulded the slugs and type are subjected to direct compression. The pressure tends to reduce the height of the type; it also seeks out any defects in the type.

Hot moulding intensifies the effects of this compression. Like all other metals, printing alloys are softer when they are hot than when they are cold. Fig. 17 shows how the hardness falls progressively when the temperature rises. For both slug casting metal and Monotype metal the hardness at 250° F. is less than one-half of the hardness at room temperature. At 300° F. the hardness is only about one-third of its original figure.

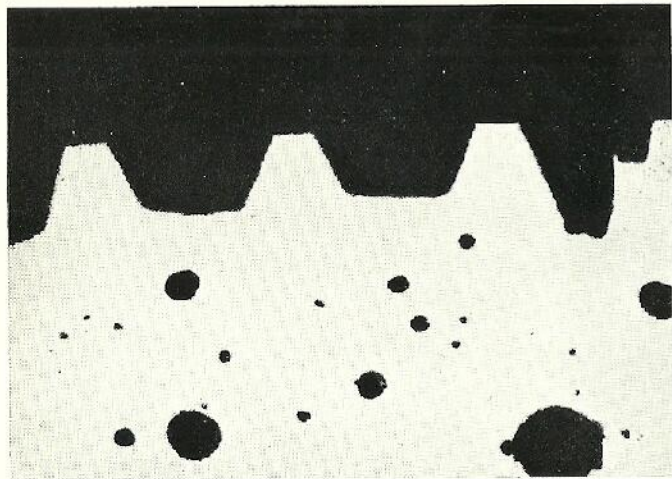


FIG. 15. Section through the face of a slug. The characters are solid
Magnification: 25 times



FIG. 16. Section through a slug. The centre character is porous and crumbly
Magnification: 25 times

In moulding flongs for newspaper work the temperature may vary from 120° F. to 325° F. according to the requirements of production speed and matrix shrinkage. At the higher temperatures, when the metal is so much

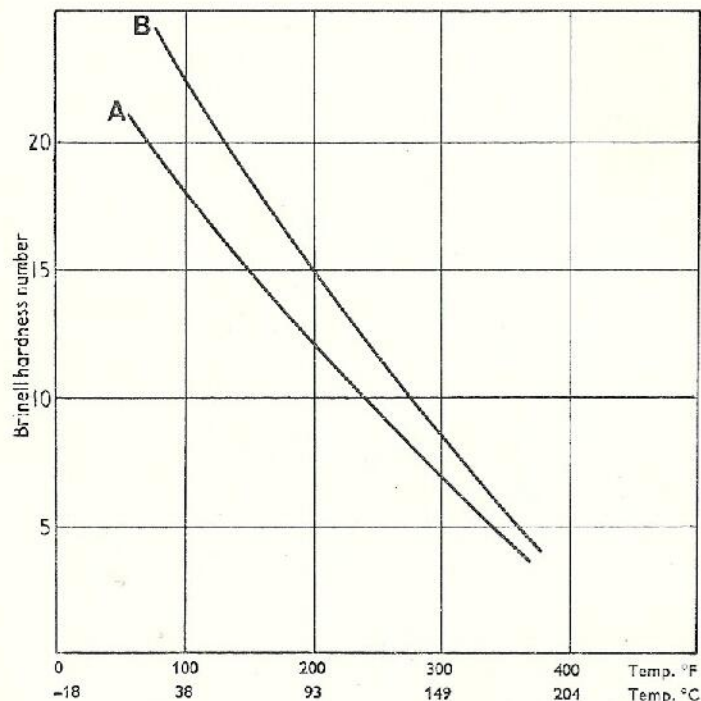


FIG. 17. Hardness of composition metal at elevated temperatures
A: Slug casting metal B: Monotype metal

softer, the best results can only be obtained by careful selection of the moulding pack and attention to moulding press maintenance.

In plastic moulding producing thermosetting moulds high temperatures are inevitable and the need for the correct moulding conditions is still greater.

All of these processes, where high moulding pressure is combined with high temperature, impose severe conditions on the type. Despite its loss of hardness the metal will usually stand up well enough to these conditions provided that the type is sound.

METALS FOR SLUG CASTING

METALS for the Linotype and Intertype machines can conveniently be considered together, since the requirements are so similar.

The casting conditions on these machines demand a very fluid and mobile metal having a short freezing range. The metal is injected into the mould through a horizontal mouthpiece; after the slug has solidified metal remaining in the mouthpiece must flow back freely.

Furthermore, to obtain speed of casting it is essential that the metal shall solidify rapidly after it has entered the mould. Rapid solidification of the large body necessitates the use of an alloy which can be cast at a comparatively low temperature.

These requirements are met by using alloys close to the eutectic in composition. The tin content may vary between $2\frac{1}{2}\%$ and 5% ; the antimony content should not be less than 11% nor should it exceed 12% , otherwise there may be difficulty in casting.

There is—as explained later—a general tendency for the antimony content of slug casting metal to rise with repeated remelting. To offset this, it is recommended that additions of new metal to the stock should contain only 11% of antimony: as a result the stock should stabilize safely at under 12% of antimony. The alloys most generally used are 3% tin, 11% antimony, 86% lead, and 4% tin, 11% antimony, 85% lead.

The higher tin content in the second specification helps

towards a finer face on the slug, and is the recommended specification.

The casting conditions on slug casting machines, therefore, necessitate using an alloy which is not so hard as other type metals. Some compensation is obtained from the support provided by the long slug. In addition, for slugs which have to withstand the pressure of moulding, solidity is more important than the hardness of the metal.

The alloys mentioned have been adopted generally as standard. Particulars of the melting-points and hardness are given in the table, which also includes other alloys which have been used for slug casting.

Composition		Completely liquid		Completely solid		Solidification range		Brinell Hardness No.
Tin %	Antimony %	°F.	°C.	°F.	°C.	°F.	°C.	
2	11	478	248	463	239.5	15	8.5	18.5
3	11	477	247	463	239.5	14	7.5	19.5
3	12	470	243	463	239.5	7	3.5	20.0
3	13	492	255.5	463	239.5	29	16.0	21.0
4	10	485	251.5	463	239.5	22	12.0	20.5
4	11	477	247	463	239.5	14	7.5	21.5
4	12	463	239.5	463	239.5	—	—	22.0
5	11	475	246	463	239.5	12	6.5	22.0

Alloys containing as much as 13% antimony have occasionally been used in the hope of obtaining harder slugs. These alloys require a higher working temperature, and it is less likely that solid slugs will be produced. Their use is not now recommended on slug casting machines.

Casting conditions. In practice, casting temperatures vary between 520° and 550° F.

Machines vary one from another, but best results are

usually obtained at casting temperatures of 530° F. to 550° F. At lower temperatures there is a tendency for solidification to occur inside the mouthpiece, which may, in consequence, become choked. Furthermore, the metal solidifies so quickly against the matrix that there is little time for air to escape; hollow characters may result which sink under the moulding pressure.

The mouthpiece and throat are heated to minimize the loss of heat and consequent chilling of the casting stream. Some operators prefer to work with the metal in the pot at a lower temperature, which permits higher casting rates, and with a high throat temperature to compensate for it, but this arrangement is not advisable; experiment and experience confirm that hollow characters are more prevalent with low casting temperatures. At the other extreme, if the metal is too hot when it enters the mould splashing results, or solidification is not completed by the time the plunger returns and the metal still liquid is sucked back, leaving hollow feet.

Solidity. For slugs to be solid there must be a full flow of metal into the mould; the throat and mouthpiece holes must be quite clear.

There must be ample pressure behind the metal stream; this entails a well-fitting plunger, adequate tension on the plunger spring, alignment of mould with mouthpiece, and maintenance of the correct level of metal in the pot.

Air must be able to escape freely from the mould as the metal is pumped in: the air grooves must be clear.

Depreciation of slug-casting metal. Depreciation in the quality of printing metals, that is the loss of tin and antimony through constant remelting, is dealt with on

pp. 60-66, but it is desirable to note at this stage that the remelting of slug-casting metal results in a slight fall in the tin content though not in the antimony content.

It is not uncommon in fact to find that the proportion of antimony increases slightly. This is especially the case in offices handling mixed formes containing 'Monotype' or foundry type in addition to slugs: only a small amount of 'Monotype' mixed in with slug metal will produce a significant increase in the antimony content. In such offices particular care must be taken to see that the antimony content of slug metal does not get dangerously high.

Typograph metal. In the Typograph machine the metal is cast through a slot instead of through mouthpiece holes. It is possible to cast a metal containing 12-13% antimony, but the use of a standard slug-casting alloy is recommended.

Metal for Ludlow machines. It is usually most convenient to use standard slug-casting metal on the Ludlow machine, but a wide range of alloys can be cast, and Monotype metal is sometimes used to avoid the necessity of sorting.

Although a Ludlow slug has a substantial body the harder metal may be used because the mould is water-cooled.

When a separate metal is desired the composition 4% tin, 11% antimony, balance lead, will give excellent results.

Metal for Elrod machines. Standard slug casting metal is suitable for casting leads on the Elrod machine.

Metal for Nebitype machines. Standard slug casting metals or Monotype composition metals are used for these machines with good results.

MONOTYPE METALS

THE harder metal which is used for 'Monotype' has superior resistance to wear in printing. The rich alloy provides a fine face to the type, especially when the proportion of tin is high.

Metals for 'Monotype' composition contain from 6 to 10% tin, 15 to 19% antimony, balance lead. The proportion of tin is usually determined on economic grounds, though 7% should be regarded as the minimum. In equal conditions the higher proportions of tin produce better and tougher type.

For routine work the antimony content should not exceed 17%. With higher antimony contents particular care is needed if the production of solid type is to be maintained. Even though the alloy is harder, yet, if the type is not sufficiently solid, it will not stand up to wear as well as type which contains less antimony but is more solid.

The recommended alloys are as follows:

7% tin, 15% antimony, or 8% tin, 15% antimony, for general composition work.

10% tin, 15% antimony, or 10% tin, 16% antimony, for composition work where fine printing and long runs are required, for type in case, and for reproduction proofs. These grades are also recommended for type which has to be hot moulded.

13% tin, 17% antimony. A special alloy for high-grade printing where good wearing qualities and excellence of face are of paramount importance.

It should be remembered that, when using the lower or

softer grades of Monotype metal, corrections will show up when introduced after a comparatively short run, the new type revealing that the old type has worn slightly even though it is still printing clearly. When it is known that a job, such as a catalogue or time-table, will be reprinted with corrections or additions, it is wise to use a high-grade metal.

The properties of these and other specifications used for 'Monotype' machine composition are given in the table.

Composition		Completely liquid °F. °C.	Completely solid °F. °C.	Solidification range		Brinell Hardness No.
Tin %	Antimony %			°F.	°C.	
6	15	502 261	463 239.5	39	21.5	23
6	16	527 275	463 239.5	64	35.5	23
7	15	503 261.5	463 239.5	40	22	24
8	15	505 263	463 239.5	42	23.5	25
8	17	520 271	463 239.5	57	31.5	27
9	19	546 285.5	463 239.5	83	46	28.5
10	15	518 270	463 239.5	55	30.5	26
10	16	525 274	463 239.5	62	34.5	27
13	17	542 283	463 239.5	79	43.5	29.5

Casting conditions. There must be correlation between:

1. Composition of metal.
2. Casting temperature.
3. Speed of casting.
4. Size of type.
5. Rate of water-cooling.

The relationship between 3, 4, and 5 is generally recognized and standardized. The interactions between 1, 2, and 3 should be considered in more detail.

For the casting temperature, a range of 650-720° F. is necessary, varying not only with the size of type being cast but also with the composition of the metal.

The casting conditions must be arranged so that after each cast, and immediately before the return stroke of the pump, the type is solid but the metal remaining in the nozzle is still fluid.

These requirements are readily reconciled if the solidification range of the alloy is not unduly large. Thus the alloys 7% tin, 15% antimony, 78% lead and 10% tin, 16% antimony, 74% lead, solidify while the temperature is falling through 40° and 62° F. respectively and uniform casting conditions can be maintained on the machine.

Compare them with, for example, the hard metal 18% tin, 27% antimony, 55% lead. This commences to solidify at 646° F. and is solid at 463° F.—a range of 183° F. By the time the foot of the type is solid in the mould, the metal in the nozzle will already have cooled below 646° F. and will have started to deposit tin-antimony crystals. Since the head of the casting stream is constantly in a pasty condition, the type is likely to be unsound and have a frosty face. The build-up of a crystalline deposit will eventually block the flow of metal.

Clearly, alloys having a very long freezing range cannot be recommended for general composition work.

Even with the normal composition metals external influences may upset the temperature balance. Thus the additional cooling occurring in colder weather or produced by a draught blowing across the machine may so chill the nozzle that casting is affected.

Speed of casting. It is not always recognized that the temperature of the mould, which has an important bearing on the product, is affected not only by the temperature of the metal and the rate of water-cooling but also by the speed of casting. A machine which is run too slowly will result in a cool mould and chilled or frosty type will be produced. The speeds recommended by the makers should be adhered to, allowance being made, when casting from harder metals, for their higher working temperature.

Temperature. Automatic temperature control represents the ideal. It must be recognized, however, that the temperature of the metal in the pot is not uniform. Local cooling is produced by conduction of heat away through the nozzle to the mould, by the return of the solid jet pieces, and by the feeding of fresh metal.

Thus while the temperature may be generally satisfactory, there may be cold spots where separation of crystals occurs, leading to the formation of a scum on the surface.

Chilled metal should never be skimmed. If a scum forms the temperature should first be raised to 730° F. and the metal thoroughly stirred to redissolve the crystals.

Feed the pot regularly. With all casting machines it is important to add metal to the pots regularly and in small amounts to ensure rapid melting and to minimize fluctuations of temperature. Most modern machines have automatic feeders, but when the metal is fed by hand it is advisable to 'preheat' it on the side of the pot. Stir the metal frequently, especially when fresh ingot metal has recently been added.

Maintenance of the correct level in the pot will materially assist in keeping the nozzle hot and will also allow the absorption of fresh metal without undue drop in temperature.

Metal for case type. When casting type for the case which is intended for use in more than one job it is desirable that the metal should be as hard and tough as practicable in order to provide the maximum resistance to abrasion. The following are some alloys which are used for this purpose:

Composition		Completely liquid °F. °C.	Completely solid °F. °C.	Solidification range		Brinell Hardness No.
Tin %	Antimony %			°F.	°C.	
9	19	546 285.5	463 239.5	83	46	28.5
12	24	608 320	463 239.5	145	80.5	33
13	17	542 283	463 239.5	79	43.5	29.5
15	25	630 332	463 239.5	167	92.5	36
18	27	646 341	463 239.5	183	101.5	38

Many offices use one grade of metal only for composition machines and 'Supercasters' and the specification recommended for this dual purpose is 10% tin, 16% antimony, 74% lead.

Difficulties associated with the use of hard metals are overcome on the 'Supercaster' by the nozzle-seating timing device which permits close control of the dwell of the nozzle in the mould.

Metal for casting leads on the 'Monotype' machine.

It is possible to use a lower grade and, therefore, cheaper alloy for casting leads and other spacing material on the 'Monotype' machine; the chief advantage, however, in

casting spacing material on the 'Monotype' is to save distribution, and this advantage can only be secured by using the same metal for leads, &c., as for type. If a lower grade metal be used it is essential that the leads should be picked out, and not remelted with the type, in order to avoid lowering the composition of the Monotype metal, and in these circumstances it is cheaper to buy leads manufactured by mass-production methods than to make them on the 'Monotype' machine. If, however, circumstances demand that a cheaper metal be used for the purpose, it can suitably contain 2-5% tin, 10-15% antimony, balance lead.

Metal for casting rule on the 'Monotype' machine.

There is the same advantage in using composition metal for rule as for leads, viz. that the rule can be remelted with the type. Rule is a printing surface and spacing material is not, and a low-grade metal will not cast satisfactory rule; the recommended alloy is 10% tin, 16% antimony.

TYPE-CASTING METALS

A CERTAIN amount of type is still cast on type-casting machines for handsetting.

Long life is expected from this class of type. The use of a metal rich in tin and antimony provides hard-wearing type and reduces the need for frequent recasting.

Typical specifications are:

Composition		Completely liquid		Completely solid		Solidification range	
Tin %	Antimony %	°F.	°C.	°F.	°C.	°F.	°C.
13	25	616	324.5	463	239.5	153	85
14	27	635	335	463	239.5	172	95.5
18	28	629	332	463	239.5	166	92.5
22	27	626	330	463	239.5	163	90.5
20	20	573	300.5	463	239.5	110	61

It will be noted that an increase in the proportion of antimony requires an increase in the proportion of tin. If a metal with a low tin content is taken and continued additions of antimony are made, the hardness of the metal will only be increased very slowly after a certain point; similarly, continued additions of tin to a metal containing a low proportion of antimony only improve the hardness to a small extent. To obtain substantial increases in hardness the proportions of tin and antimony must be raised together. It is interesting to record that the English type foundrymen generally followed this practice long before metallurgists revealed its theoretical soundness.

Casting conditions. Type-casting machines are designed to overcome the difficulties associated with the use of hard metals. The type is cast in a horizontal position. The temperature of the metal, nozzle, and mould can be kept high. The metal has only to travel a short distance on casting.

Speed of casting must be slow enough to allow sufficient time for solidification of the high melting-point alloy.

Copper in type-casting metals. The introduction of copper substantially increases the hardness and wear resistance of hard metals.

If the copper content is held carefully at a safe level it remains dissolved in the molten alloy at the normal melting-point and is without detriment to the casting properties.

The amount of copper which may safely be added varies with the tin and antimony contents of the alloy; with 10% tin, 24% antimony it is 0.5%; with 24% tin, 24% antimony it is 1.3%.

It must be clearly understood that such additions are only valuable in these rich alloys. Copper in metals for composing machines may cause endless trouble. Thus in slug-casting metal a copper content of 0.1% is already at a dangerous level because the alloy cannot retain much copper in solution at the casting temperature.

Casting script. For casting script and other kernal type it is desirable that the metal should be very fluid and tough. These qualities are achieved by using an unusually high proportion of tin to antimony content. The alloy 20% tin, 20% antimony, and 0.8% of copper is excellent for the purpose.

STEREOTYPE METAL

STEREOTYPING differs from other type-casting processes in the size of the cast, the flow of the metal, and the use of a non-metallic mould surface. The nature of flong imposes a limit on the casting temperature which can be employed, and this in turn makes alloys of high melting-point difficult to use, particularly in casting machines.

The properties of typical alloys used for stereotyping are as follows:

Composition		Completely liquid °F. °C.	Completely solid °F. °C.	Solidification range		Brinell Hardness No.
Tin %	Antimony %			°F.	°C.	
5	15	509 265	463 239.5	46	25.5	23.0
6	15	502 261	463 239.5	39	21.5	23.5
7	15	503 261.5	463 239.5	40	22	24.0
8	15	505 263	463 239.5	42	23.5	25.0
9	15	509 265	463 239.5	46	25.5	25.5
10	15	518 270	463 239.5	55	30.5	26.0

Metal for casting stereotypes, both flat and rotary, should contain 5-10% tin, 15% antimony, balance lead. The proportion of tin is often dictated by economic factors, but for long runs at least 7-8% is desirable. For plates of the highest quality and wear resistance the alloy recommended is 10% tin, 15% antimony, 75% lead. At times slightly higher proportions of antimony have been used for casting stereo plates, but this is not recommended; experience

has amply proved that stereo plates containing 15% antimony will stand the stresses on fast-running presses, and that toughness can be obtained by the inclusion of an adequate proportion of tin.

Lower antimony contents—13½%— are common in American practice. The casting temperature can be lower, thus facilitating high rates of casting. There is a material reduction in the wear resistance, however, and a change to such a low content should be made only if it is dictated by the casting conditions.

Casting temperatures. In the hand casting of flat plates the metal is cooled in the ladle below the liquidus temperature before casting. The metal in the pot should of course be kept completely molten to avoid separation of tin-antimony crystals; a temperature of 560° F. is recommended, i.e. approximately 50° F. above the liquidus temperature of the metal.

The majority of stereo casting machines are water-cooled, and stereo metal in the pot has to be at a higher temperature than for hand-casting to ensure sufficient fluidity of the metal in the casting box. In addition, if the metal is pumped from the pot to the casting box some of its heat is lost. The casting temperature should generally not exceed 600° F., but there must be sufficient heating capacity to maintain the pot temperature without undue fluctuations when black plates or new ingots are being added.

Temperature during standby periods. Freezing and separation of tin-antimony crystals from stereo metal containing 10% tin, 15% antimony, 75% lead, commence on cooling to 518° F. During standby periods the tempera-

ture of the metal should be maintained above this figure, otherwise separation will take place and it will subsequently be difficult to redissolve all the separated crystals. Before casting is recommenced the temperature should be raised rapidly to the casting temperature and the metal thoroughly stirred in order to take into solution any crystals which may have separated.

The stirrer should not be started until the metal has heated up again; otherwise there is the danger that crystals will become entangled with the dross.

The importance of the 'tail'. A stereo plate should be cast with a substantial 'tail'. (The term 'tail' is commonly used in the printing trade, though engineers and metal founders call it a 'head'.) This provides a pressure which forces the metal beneath into the detail of the mould. Equally important is its effect in supplying a reservoir of metal which remains molten until all the plate is solid.

Shrinkage of solidifying metal. As the metal solidifies it shrinks in volume by about 2%. This is quite distinct from the contraction of the solid metal as it cools subsequently to room temperature.¹

The effects of shrinkage can clearly be seen when an ingot of stereo metal is cast. The metal sets first on the bottom and sides, where it is in contact with the cold mould, thus forming a solid shell. The remainder of the metal solidifies—and shrinks—inside this shell; as solidification proceeds inwards the shrinkage in volume causes the

¹ Contraction of the solid metal is important to the stereotyper in another connexion. In conjunction with the shrinkage of the matrix, it determines the final size of the plate.

level of the fluid metal to fall progressively. In this way the familiar depression is formed on the top of the ingot.

After a while the outside of the ingot is hard but the centre is mushy, a mixture of solid crystals with still liquid metal. By this time the crystals are so packed that there can be little further fall in the general surface level; but the shrinkage continues as the last metal solidifies. Therefore, the remaining liquid is drawn away from the surface crystals, leaving small cavities between them.

If a broken ingot of metal is examined the last portion to solidify often looks spongy; the cavities left by the shrinkage may extend well below the surface.

Shrinkage in stereo casting. Shrinkage then leaves cavities in the last portion of the metal to solidify. An effective tail feeds the shrinkage in the plate; any cavities will be in the tail, not in the plate.

In normal conditions a plate starts to set at the bottom. When this first metal solidifies it shrinks, thus causing the level of liquid metal in the box to fall. As solidification proceeds up the plate so the shrinkage is 'fed' by liquid from above. Towards the end the metal in the tail is in a pasty condition and the withdrawal of liquid from this to feed the shrinkage below leaves the tail porous.

The tail must continue to feed the plate until the latter has set completely. The practice of using a 'bolster' above the matrix is valuable; it helps to keep the feed channels open by retarding the cooling of the metal immediately above the plate.

Irregular cooling. For perfect feeding the plate should solidify regularly from the bottom upwards. With a body

of metal as large as a stereo plate cooling cannot be perfectly regular.

The embossing of the matrix produced by the impression of the forme is one cause of irregular cooling. As the plate cools heat must travel outwards. Heat is extracted more quickly through the parts of the matrix which are in direct contact with the box. Other parts of the matrix—those which form the 'whites'—are held away from the box; cooling here is slower.

Thus the metal in a white may remain liquid after all around has solidified. This last liquid, cut off from supplies of feed metal, will contain cavities.

Cokey face. The appearance of shrinkage cavities on the face of the plate produces the condition known as 'cokey face'. It will be clear from the above explanation why cokey face usually appears in the whites.

When cooling is delayed over a larger area the cokiness may be more widespread. This may happen, for example, if one part of the box is hotter than the rest or if a section of the matrix is overheated by the flow of metal into the box.

Wherever a pocket of liquid metal is left liquid after the surrounding metal has set, cokey face may appear. But it need not do so. If the metal at the face solidifies while there is still liquid metal behind it the face will be fed from behind and will be solid. Shrinkage cavities will then be dispersed into the body.

The more the metal can be encouraged to solidify first on the face, the more deeply are the cavities thrust harmlessly away into the body of the plate.

Sinks. If a large area of the plate lags far behind the rest

in cooling the total shrinkage on solidification may be so great as to draw the face bodily inwards, producing a 'sink'.

The cooling conditions must be seriously upset for this to occur. One cause is the impingement of the metal stream on one spot on the matrix, particularly if the casting temperature is high; another, the localized growth of scale in a water-cooled casting-box, producing a hot spot on the box and thereby delaying the cooling of the adjacent metal.

Casting conditions in stereotyping. The golden rule in stereotyping is cool metal and a hot box. This cannot be too strongly emphasized, because neglect of the rule is the most frequent cause of defective plates. The box should be hot enough to make it uncomfortable to keep one's hand on it.

To secure satisfactory plates the ideal is regular progressive solidification from the bottom upwards. Since this is often upset by irregularities in cooling, the metal at the face should be encouraged to solidify ahead of the metal in the body of the plate. The face will then be perfectly fed and any shrinkage cavities which occur will be towards the back of the plate.

This second aim is difficult to maintain because flong is a poor conductor of heat and thus tends to delay the solidification of the metal in contact with it. The object of using a casting-board when pouring flat plates is to delay solidification at the back also and thus to avoid drawing feed metal from the face; the same result is achieved on rotaries by working with a hot box.

In rapidly operated rotary casting-boxes water-cooling

is necessary, not to keep the casting-box cold, but to prevent it from overheating.

It is easier to obtain a good casting in a thick plate than in a thinner one; a 12-pt. stereo plate is usually sounder than a 10-pt. plate.

Cast stereo plates with cool metal. The approach to the condition in which the metal would solidify first on the face of the mould is assisted by casting the metal at as low a temperature as possible. Then solidification takes place rapidly throughout the plate and does not leave a more fluid portion near the face which may develop contraction cavities.

Slow cooling produces a coarse structure. A further objection to high casting temperatures is that the metal may have a coarse structure; with the slow cooling the tin-antimony crystals grow large and may separate into clusters. Plates then tend to be brittle and to wear unevenly.

With rapid solidification the tin-antimony crystals are fine and uniformly distributed throughout the plate.

At the other extreme, if the metal is cast at too low a temperature it will not flow freely over the matrix surface, leaving chill marks and frostiness.

Porosity due to entrapped air. When a plate is poured a certain amount of air is entrained with the metal. Some escapes upwards before the metal solidifies; the rest is trapped in the plate.

The air rises through the most fluid portion of the metal. Those casting conditions which encourage the metal to solidify first at the face also help to channel the rising air bubbles away from the face and into the body of the plate where they are less harmful.

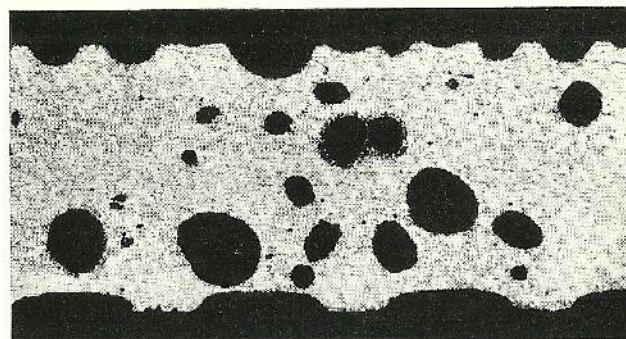


FIG. 18. Section through Stereo plate. Porosity caused by entrapped air bubbles

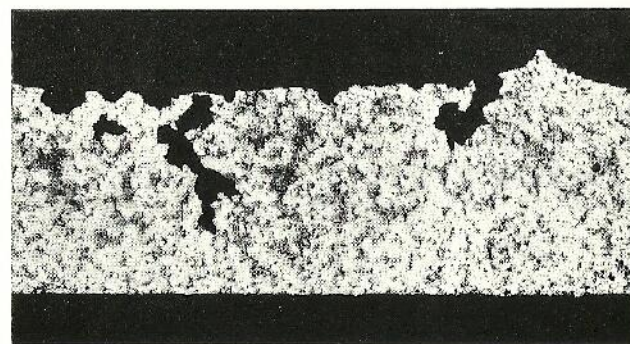


FIG. 19. Section through Stereo plate. Shrinkage cavities in the metal producing cokey face

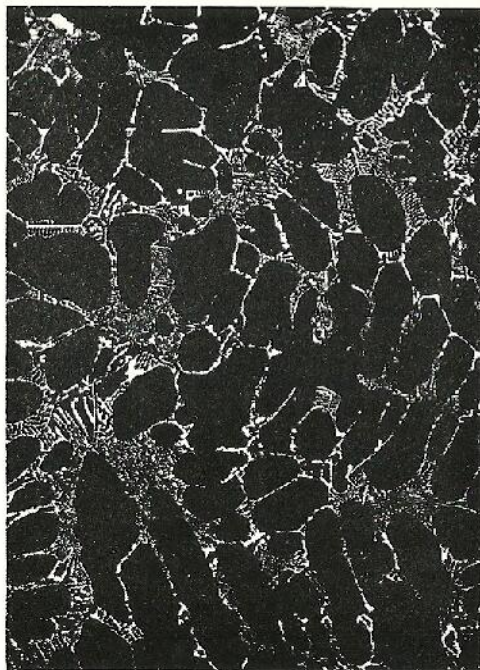


FIG. 20. ELECTRO BACKING METAL

2% tin
3% antimony
95% lead

The main constituent is lead with a small proportion of eutectic surrounding the primary crystals

Magnification: 100 times

Impurities such as copper which tend to make the metal less fluid obstruct the escape of air and increase the porosity.

Entrapped air bubbles are a source of weakness in plates. They are rarely present in flat plates cast by hand when the metal enters the box in a smooth stream. In rotary casting-boxes metal pumped in at high speed is inevitably aerated, but unless cooling is over-rapid there is time for most of the air to escape.

If plates are honeycombed with air bubbles the reason may be

- (a) Distortion or misalignment of the spout producing a turbulent cascade of metal into the box.
- (b) Excessive cooling preventing free escape of the air.

Solid metal mounts. It is customary and convenient to cast solid metal mounts for internal use in stereo metal. A cheaper metal will serve the purpose and if a separate metal is required the composition 2% tin, 10% antimony, 88% lead is recommended.

ELECTRO BACKING METAL

THE requirements for metal for backing electro shells are that on casting it shall bond firmly with the tinned shell and provide a solid support for the surface, and that on the press it should have adequate strength to resist compression. As the wear on the plate is borne by the shell there is no advantage in using a hard backing metal. Too hard a metal makes slabbing more difficult if not impossible.

Electro backing metal is the only printing alloy which is substantially below the eutectic in composition. The alloys in general use contain 2-4% tin, 2-4% antimony, balance lead.

The properties of typical alloys are as follows:

Composition		Completely liquid °F. °C.	Completely solid °F. °C.	Solidification range		Brinell Hardness No.
Tin %	Antimony %			°F.	°C.	
2	2	585 307	463 239.5	122	67.5	10.0
2	3	572 300	463 239.5	109	60.5	11.0
3	3	563 295	463 239.5	100	55.5	12.0
4	4	545 285	463 239.5	82	45.5	13.5

When electro plates have to be curved after being backed-up it is advisable to limit the antimony content to a maximum of 3%.

Casting conditions in backing. The shell must be tinned to provide the bond with the backing metal which is essential for firm support. Additionally, the tinned coating assists the flow of the backing metal so that it more

surely displaces air or flux in the recesses of the shell which might otherwise cause soft spots.

The shell is first fluxed to remove any oxide on the copper, thus producing a chemically clean surface with which the tin can alloy. A sheet of tin or solder foil is laid on the heated shell and allowed to melt. Alternatively, the shell may be pre-tinned by electro plating, but care must be taken that an adequate thickness is deposited.

Before backing-up the shell should be hot enough to keep the tinned coating molten. Overheating causes the tin to become seriously oxidized or 'burnt' and ruins the bond between shell and backing.

New processes have been developed with the objects of producing a denser backing and truer surface. In one the plate is pressed between platens after the metal has been cast. The centrifugal process has been introduced for the backing of curved shells. The shell is placed inside a cylindrical box and rotated at high speed; when the metal is poured in, the centrifugal action produces a powerful thrust many times the force of gravity.

Age hardening. After being cast some metals become harder in course of time. This occurs with electro backing metal. Experiments show that these alloys achieve maximum hardness about 48 hours after casting. Backing metals containing the higher proportions of tin harden more rapidly.

QUALITY AND THE EFFECT OF IMPURITIES

A GOOD printing metal should be:

- (a) accurate to specification;
- (b) made from high-grade materials, so that it is free from harmful impurities;
- (c) properly alloyed, so that it is thoroughly mixed, and free from oxides.

Manufacture. By using low-grade materials and by short-cuts in the manufacturing process it is possible for the manufacturer to produce more cheaply; the resultant metal may not necessarily differ greatly in appearance, nor may an analysis reveal divergence from the specified proportions of tin and antimony, but the working properties are not likely to please the printer. Impurities or poor mixing produce bad castings, choked mouthpieces, and excessive dross; it is true also that the proportions of tin and antimony in such a metal depreciate more quickly.

There is, unfortunately, no ready means of detecting poor metal by appearance. The safe plan is to buy from a reliable and experienced manufacturer who appreciates this possibility and protects the printer.

Cost. Unlike paper and ink, printing metal remains for further service when the job has been completed. The real cost is the depreciation in weight and quality which the metal sustains as the result of its use, and the labour and fuel cost of remelting into ingots again.

This charge is only a small proportion of the labour and machine charge for composing and casting. It is virtually a negligible factor compared to the cost of the printed job, including the paper and ink, make-ready, proofing, and printing. Further, if delays are caused through faults in the slugs, type, or plates, additional labour and machine costs can be incurred.

It is wise, therefore, not only to use good quality metal, but also to choose the best specification for the job irrespective of first cost. The extra expenditure is small compared with the advantages in the machine room of sharp, hard-wearing type or plates.

Equally, it is clear that once the right metal has been bought it pays to maintain the standards of purity and composition, either by careful remelting and reviving or by having the metal refined by the manufacturer.

Appearance of printing metals. Printing metals, when molten and freshly skimmed, should have a bright mirror-like surface. This may presently be broken by hair lines, like a spider's web. Some impurities affect the appearance of the molten surface; a small trace of zinc, for example, will cause the mirror of a freshly skimmed surface to cloud over almost immediately.

Impurities in metals. Although great progress has been made recently in the metallurgy and refining of metals, no metals in common use are entirely free from impurities.

Most of the metals can be obtained today in a state of high purity such as 99.99% if the need requires, but so-called pure metals in commercial use may contain 0.1, 0.25, or even 1% of impurities. For many purposes it is

not the total but the character and amount of individual impurities which is of importance to the user.

Some impurities can be tolerated within certain limits, which is fortunate because contamination can so easily occur when a metal is continually remelted. Others, like zinc, are extremely harmful in printing metals and even in minute quantities make it impossible to secure satisfactory castings.

Copper. Copper is the impurity most commonly found in printing metals, from contamination with cuttings from half-tones, shells, and brass rule.

Copper is slowly taken into solution by molten printing metals and on continued remelting the copper content of the stock gradually rises.

A small proportion of copper in slug casting or Monotype composition metal is harmless. Above this proportion the copper forms a compound with antimony. This compound crystallizes as flat leaf-like crystals which are very hard and which freeze out of solution at a temperature higher than the first freezing-point of the type metal. Even when the quantity of such crystals is small they tend to concentrate in the throat or mouthpiece of the casting machine as the metal flows past.

The build-up is cumulative and ultimately the choking becomes so pronounced as to stop casting.

Copper then must be regarded as an injurious impurity in metals for mechanical composition and great care should be taken to ensure that it is not introduced into the melting-pot when remelting slugs and type.

In metals used for founder's type copper is often intentionally added since it hardens the metal. These metals

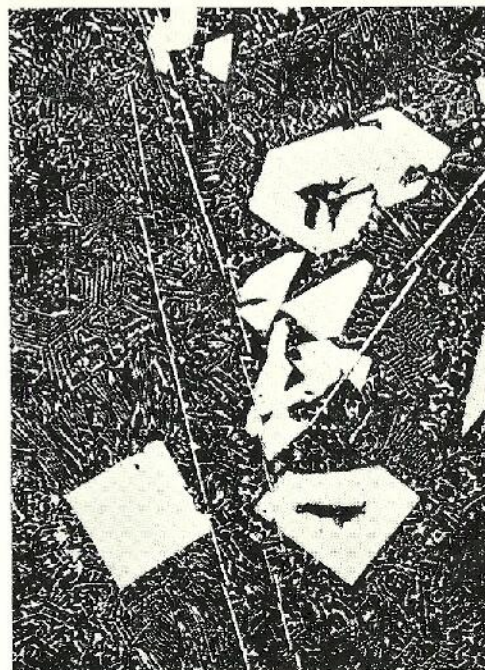


FIG. 27. Photomicrograph of Monotype metal contaminated with 0.5% of copper. The long straight 'needles' are in reality sections cut through flake-shaped crystals of copper-antimony compound

Magnification: 250 times

have high antimony contents and can hold up to 1% or even more of copper (depending on the antimony content) in solution at the comparatively high casting temperatures which are employed.

A frequent cause of trouble in the past was the habit of attempting to enrich composition metal by adding a proportion of old founder's type. The motive was good for most old type is rich in tin and antimony; unfortunately it contains copper as well.

Nickel. Nickel in a printing metal has an effect similar to that of copper but more pronounced. Nickel in quite small proportions will cause trouble on composing machines. The compound of nickel and antimony which is formed has a relatively high melting-point and readily settles out on the cooler parts of the metal passages.

Similar conditions do not exist in the casting of plates and nickel is therefore less harmful in stereo metal. Nevertheless, it tends to cause formation of scum and it must still be regarded as an objectionable impurity.

Contamination is most likely to arise from the remelting of plated stereos. Fortunately, nickel does not dissolve readily in molten type metals; if in remelting care is taken to avoid overheating, and the shells are skimmed off as soon as possible, no harm should be done.

Zinc. This is the impurity which can cause the most serious trouble in practice.

Zinc is used in quantity in printing offices; in a more or less pure form as zincos and alloyed in brass rule. The danger is that a few thousandths of 1% of zinc in a printing metal is sufficient to ruin the casting quality.

Small cuttings and sawings are most liable to cause contamination. Although zinc has a melting-point of 787° F., appreciably above normal working temperature, it will nevertheless be dissolved if it remains in contact with molten printing metal. Brass is more resistant but may be absorbed if rule is charged into the remelting-pot.

The effect of zinc in a printing metal is to foster the formation of a thick tough oxide skin wherever the molten metal is exposed to the air. The amount of dross is thereby directly increased and worse, the strong skin tends to enclose drops of molten metal. However well the fluxing be carried out the dross skimmed off is not a fine dry powder, but 'fat' or scum containing a good deal of entangled metal.

Just as serious is the effect on the quality of the cast type or plates. Sharpness of reproduction depends on the penetration of the metal into the farthest recesses of the mould. When zinc is present flow is sluggish and the oxide skin holds the metal back, preventing deep penetration into fine detail.

Fortunately, the presence of zinc is immediately manifest in the appearance of the metal. Clean molten printing metal should show a perfectly clear mirror surface when it is skimmed. On the other hand, metal contaminated with zinc will not dross off cleanly. A skimmer drawn through the surface drags the skin along with it; the metal behind has a thick pasty appearance because a new skin forms immediately.

If a batch of remelted metal is thought to be contaminated it should be isolated before the trouble spreads and returned to the refiner. Zinc is not easily removed with

the plant available in a printing works. Prevention is easier as well as better than cure.

Aluminium is somewhat similar to zinc in its effects. While it is not easily dissolved by molten printing metals, care should be taken to keep any aluminium out of the dross bin and the remelting-pot. Milk bottle tops are often an unsuspected source of this metal.

Iron. Iron in small traces is a common impurity; when it is realized that iron is generally contained in the original ores, is used in the extraction of the metals, and further, that the alloys are mixed and remelted in iron pots, it would be surprising if some small proportion of iron were not present. There also occurs a gradual absorption of minute quantities from the melting-pots of composing machines and stereo plants. The trace of iron normally present is not harmful.

Oxides. Oxides, i.e. dross in fine particles, must be regarded as impurities and moreover are difficult to discover by analysis. A tiny particle of oxidized metal acts as a nucleus; the surrounding metal adheres to it and is contaminated by it, thus increasing the formation of dross. This oxidized metal will choke the mouthpieces and nozzles of composing machines. Careful cleaning and ingotting of the metal, as described on pp. 67-69, will ensure that the oxides are not carried forward to the casting-pots.

MELTING LOSS, FLUXES, AND DEPRECIATION

PRINTING metals when molten oxidize where they are exposed to the air. The skin forming on the surface is composed of oxides of lead, antimony, and tin. Left by itself the molten alloy does not oxidize very rapidly; the skin once formed provides some protection against further oxidation by the air in normal conditions.

In practice, however, the surface is frequently disturbed. Fresh metal is then exposed to oxidation and droplets of metal become entangled with the oxide. The resultant mixture of oxide and metal constitutes 'dross'. The bulk of the dross is further increased by the carbonaceous residues from ink and paper and like materials which burn when the metal is remelted.

Some dross is inevitably formed whenever metal is melted, but any excess represents waste. Lighter drosses are the reward of cleanliness and care in working the metal. This applies throughout all melting and casting operations but has particular force in remelting.

How to reduce melting loss. Any foreign matter which might harm the metal or unnecessarily increase the bulk of the dross should be kept out of the remelting-pot. Metallic impurities like zinc, besides spoiling the casting properties also produce a thick scum on the surface, which heavily increases the amount of dross.

Careful control of working temperature is essential. Prolonged overheating seriously increases the loss of metal by oxidation. On the other hand, if the pot is skimmed

cold, or before the metal is fully melted, much good metal is taken off with the dross.

Type and slugs usually contain air bubbles which are released when the metal melts. Unless the temperature is adequate the bubbles do not escape completely but form a frothy scum at the surface. To break down this scum and produce a clean separation of metal from dross the remelting-pot should be heated to 50-100° above the temperature used on the casting machines.

Fluxes for printing metals. The use of a flux should be regarded as an essential part of the operation of metal melting. Not only does it help to clean the metal and thus ensure good printing results, but it reduces the melting loss considerably. If flux is not used the dross skimmed off is probably much too heavy. A flux properly used will release the good metal entangled with the dross and so reduce the wastage.

There are many materials which might be used as flux. In selecting the best, consideration has to be given to other factors, beside their apparent effectiveness; some fluxes contain ingredients which have a corrosive effect on cast iron, steel, brass, and bronze, and these obviously should be used with care lest any flux is carried over to the composing machines; others tend to remain entangled in the metal for some time and to impede free flow.

Fluxes such as resin, tallow, butchers' fat, etc., do not ignite readily, and instead of burning with a hot flame they form clouds of fumes which are in themselves objectionable and serve no useful purpose.

A flux for printing metals should have no volatile constituents which are corrosive or injurious, and should leave

no residue in the metal which might impede the action of the pump plungers. Such a flux can be obtained in suitable tablets; it helps to disentangle any oxides and dirt from the body of the metal and, by burning with hot flame, applies a high local temperature to the surface of the metal, thus releasing the good metal from the scum and leaving behind only a fine powder, which may then be removed.

Depreciation. The dross skimmed from molten printing metals contains slightly higher proportions of tin, and usually of antimony, in relation to lead than the metal itself. This is because:

- (a) Although all three constituents suffer oxidation, tin, and to a lesser degree antimony, are more quickly oxidized than lead.
- (b) If the metal remains for any period in a semi-molten condition, tin-antimony crystals tend to separate to the surface. The crystals do not readily return into solution at normal working temperatures and are liable to be skimmed off with the dross.

These two distinct effects combine to produce a gradual depreciation of the tin and antimony contents of the metal.

Reducing depreciation. The greater part of the loss occurs during remelting and the precautions necessary to keep losses low have already been outlined. The loss on casting machines may, however, be considerable if care is not taken.

It is advisable to melt the metal from cold as rapidly as possible. Directly the metal is molten the operator should

stir the pot vigorously and also when fresh ingots are added during the day. The object of these precautions is to ensure that the tin-antimony crystals are quickly taken into solution.

If separation of the rich constituents occurs, as evidenced by the presence on the surface of the metal of a thick white scum, do not skim this material off but raise the temperature of the metal and stir well. The temperature can safely be raised for a brief period by 100° F. above the normal casting temperature when, after vigorous stirring, the separated crystals will be redissolved.

A current of cold air passing over the surface of molten metal encourages the formation of dross.

In stereo pots, as in composing machines, melt the metal rapidly, stir frequently, and keep the hood of the pot closed as much as possible. When stereo metal is kept continually molten, as in daily newspaper production, the temperature should be maintained, when the pots are not in use, above the level at which tin-antimony crystals commence to separate.

Extent of depreciation. For estimating purposes it is usually assumed that the total depreciation in weight and composition of composing-machine metals is 4% of the value of the metal used; this estimate covers the double operation of casting the type or slugs and remelting them into ingots ready for use again. The figure of 4% is a safe one to use for estimating purposes, but the works manager should not be satisfied with it. By careful attention and with first-quality metal the loss can be reduced to about 2-3%.

The result of depreciation. Unless the tin and antimony which are lost during use are replaced, it is obvious

that printing metal will gradually change in composition and the working qualities of the metal will be affected. The regular addition of new metal to the old stock helps partially to maintain the quality, but when insufficient metal is added it is necessary to add reviving alloy regularly.

Reviving alloys. Experience has revealed the extent of the average loss of tin and antimony each time a printing metal is used, and on the basis of these figures reviving alloys have been designed containing high proportions of tin and antimony so adjusted that the addition of $\frac{1}{2}$ lb. per cwt. of the alloy at each remelting will restore the tin and antimony wastage. The regular addition of this small quantity of reviving alloy is recommended in preference to adding a substantial quantity of reviver at irregular intervals.

Since some of the metal in printing works is locked up for long periods, while other metal is used again and again, the quality of the stock is liable to become irregular. This tendency is not corrected by adding reviving alloy at intervals to that part of the stock which happens to be in circulation at the moment and not to the remainder. If, on the other hand, a small proportion of 'reviver' is added with each potful of metal, as and when it is remelted, the whole stock remains reasonably uniform.

Different reviving alloys are necessary for various classes of metal, because the rate of loss of tin and antimony varies with the different metals. Thus certain reviving alloys are made for Monotype and stereotype metals and others for slug-casting metals.

The case for the regular addition of reviving alloy to composing-machine metal does not apply with quite the same force to stereotype metal, especially in rotary stereo

plants, where the whole of the stock is in regular use and so depreciation is more uniform, and where new metal is usually added regularly and becomes evenly mixed through the stock. If the proportion of new metal is sufficiently high the standard can be maintained without adding reviver, but if insufficient new metal is added a small weekly addition of reviving alloy may be made to each pot, the quantity and composition of the alloy being determined by the rate of depreciation revealed by analyses over a period. Alternatively, depreciation may be permitted to an agreed level of composition before adding reviving alloy.

Check assays. It is desirable that the quality of all printing metals should be checked by analyses regularly. Where metal is turned over quickly this should be done every one or two months. In the average jobbing works it should be sufficient to have a check analysis made every six months. Reputable metal suppliers are prepared to analyse metal for their customers free of charge, and advantage should be taken of this valuable service. It avoids guesswork and helps the printing works manager to standardize methods and production.

Sampling. Great care is necessary to secure an accurate sample. Unless the sample sent to the chemist is representative of the bulk the analysis will be misleading and possibly worse than useless.

As a rule it is desired to know the average composition of the metal being used. The following methods of sampling are then recommended:

Slugs. Take a slug from each of several machines on two or three consecutive days.

Monotype. Take a few stamps from each machine on two or three consecutive days.

Stereo plates. A section 2 inches square cut from a rotary plate is an excellent sample: the plate will have been cast when the metal is well stirred. A section of a flat stereo is also satisfactory if the metal is thoroughly stirred before the plate is cast.

In all cases send the whole sample for analysis; do not remelt it first.

Sampling molten metal. The metal must be completely molten and drossed off. Stir it thoroughly, then immerse a small ladle in the metal for a minute to allow it to heat up, dip out a small quantity— $\frac{1}{4}$ lb. is ample—and pour it all quickly into a cool mould of thin flat section. The rapid cooling of a sample of this shape avoids segregation. No attempt should be made to trim the sample in any way.

Sampling ingots. Select a proportion of the ingots, say one in twenty, and take sawings from them. This should be done by making three or four vertical saw-cuts extending from the side of the ingot to the centre, alternate saw-cuts being taken from opposite sides.

The reason for this precaution is that no ingot is uniform; there is always segregation within the ingot itself. This segregation is severe with large ingots which cool slowly and slight with thin flat ingots. Drillings from the top and bottom of any large ingot of type metal reveal differences in composition. The method of sawing described ensures fair sampling of the ingot. A corner knocked off an ingot does not constitute a representative sample.

THE REMELTING OF SLUGS AND TYPE

It is unwise to put slugs or type straight back into the composing machines. They should always be remelted so that clean ingots only are fed to the pots.

The work of remelting.¹ There is no difficulty in this work but it is an important task. Lack of care in remelting can cause delay and expense in the composing machines.

It is best to train a man for the job and let him devote all his time to it while the work of remelting is in hand. This is mentioned here because it is sometimes the practice to entrust the work to the latest junior, or to expect it to be done by someone who is attempting to carry on other duties at the same time.

Keep metals separate. Make sure that all the metal is of the same grade. Slugs must be kept separate from 'Monotype'; leads, metal furniture, stereos, and electros should be carefully sorted and put to one side.

All 'foreign' metals such as zincos, copper plates, and brass rule must be rigorously excluded, as they would introduce harmful impurities.

Founder's type also should be kept out; besides having a high content of antimony, such type frequently contains a small amount of copper which is harmful in metal for composing machines.

The melting-pot. Melting small quantities of metal is

¹ A more complete description is contained in *Efficient Remelting* published by Fry's Metals Ltd.

inefficient in fuel and labour; more important, it increases the liability to variation throughout the stock of metal. The melting-pot should hold at least 500 lb.

The pot may be heated either by gas or electricity. Gas is cheaper both in first cost and fuel consumption. Electricity is cleaner but in either case a hood and ducting must be provided to carry away the fumes from the pot.

A melting-pot fitted with a bottom pouring device is to be preferred. It saves labour and ensures that clean metal free from dross is poured in the moulds.

Temperatures. Temperature control is important. When metal is seriously overheated excessive formation of dross results; on the other hand, if the temperature is not high enough the tin-antimony crystals will not be in complete solution and will then segregate to the surface to form a rich scum. If this happens a considerable amount of heat, together with vigorous stirring, is necessary to redissolve the scum.

These difficulties are avoided if the metal is heated rapidly to the correct temperature, which is a little above the casting temperature on the composing machines:

600° F. for slug-casting metal.

700° F. for mono composition metals.

750° F. for dual purpose mono and display metals.

A thermometer should be used to check the temperature.

Cleaning and reviving. When the required temperature is reached the metal should be cleaned with a suitable flux. A non-corrosive flux is advisable. The flux not only cleans the metal but lessens the melting loss by reducing

the dross to powder, releasing good metal entangled with it.

The dross should be removed with a perforated ladle and immediately dropped into a covered container. The sides of the pot should be scraped with the ladle to bring all the dross to the surface of the metal.

The addition of reviving metal at this point counterbalances the loss of tin and antimony in the dross. An addition of $\frac{1}{2}$ lb. of reviver for each hundredweight of metal in the pot will maintain the correct composition. The reviving alloy should be thoroughly stirred in.

Stir the metal at intervals during the pouring.

Pouring the metal. For pouring, the metal can with advantage be some 50° cooler than for drossing. When the ingots are poured they should cool quickly to avoid the growth of coarse crystals. Moulds should be cool to ensure rapid chilling.

As the metal is poured the motion may produce a small amount of oxide or aerated froth on the surface of the ingots. Each ingot should be skimmed immediately after pouring, while the metal is still molten, to leave a clean bright surface. A thin piece of sheet iron, the width of the ingot, bent at right angles and narrowed to form a handle, makes a suitable skimmer.

Appearance of ingots. The ingots, when broken, should show a bright crystalline fracture, varying in size of crystal according to the amount of antimony and tin present and the rapidity of cooling during the process of solidification. The size and form of moulds also have a great influence on this feature, a massive ingot tending to the formation of coarse crystal grain due to relatively slow

cooling. The same alloy cast into small ingots, which cool and solidify quickly, exhibits a much finer crystal structure when broken. It is unwise to attempt to judge the quality of metal by the appearance of the fracture; specimens cast in identical conditions can be compared, but experienced men are usually chary of forming an opinion on the evidence of fractures, because they know how many factors can influence crystal structure.

Fumes. Fumes from the remelting of type and slugs arise from the decomposition of ink and floor sweepings and not from the metal; they are sometimes objectionable but not poisonous. A little care in keeping the hood closed until the metal has melted and the fumes have dispersed will obviate most of the unpleasantness. Volatilization of printing metals does not occur at normal working temperatures, and danger to health on that account need not be apprehended.

TEMPERATURE CONTROL AND MEASUREMENT

CONSTANT reference has been made to the desirability of controlling temperature—whether on composing machines, for stereotyping, or in remelting.

The fitting of thermostats for the automatic control of temperature has contributed much to the large measure of improvement in the average quality of commercial production, raising it close to that secured in showroom conditions.

It is also desirable for the operator to know the working temperature; hence a means of indicating temperature should be fitted if one is not incorporated with the thermostat.

The thermometer and the thermostat detector should be sited with care. Temperatures are apt to vary from point to point in the pot unless there is constant stirring. The stem should therefore be located so as to indicate the temperature of the metal being cast, not for example as locally affected by proximity to the heaters.

Thermometers or pyrometers should be compared from time to time with an instrument kept for the purpose. An inaccurate thermometer is worse than useless—it is misleading.

Thermometers. Mercury-in-glass thermometers are the cheapest instruments for measuring temperature, and if used carefully may give satisfactory service for a long period. They are, unfortunately, fragile and are liable to

become erratic after being in use for some time. It is essential that thermometers for this class of work should be made from borosilicate glass, because ordinary glass expands and does not contract again to its original dimension. There is also a liability to a break or gap in the column of mercury which, if unnoticed, will result in false readings.

Mercury-in-steel thermometers are accurate for temperatures up to 950° F. and are cheaper than electrical pyrometers. They depend on the expansion of mercury in a steel tube, the resultant force being transmitted through a capillary tube, acting as a hollow coiled spring after the manner of a Bourdon pressure gauge and so registering the temperature on a calibrated scale.

Thermometers should be compared with other thermometers (or pyrometers) at constant intervals to check their accuracy.

Pyrometers. Electrical pyrometers can be used to measure still higher temperatures. They are operated by the difference in potential set up by the application of heat to the junction of two thin wires made of different metals and encased in steel sheathing; the latter is immersed in the melting-pot, and the current generated is registered by a galvanometer needle on a calibrated scale. Electrical pyrometers can be used as recording instruments, making a permanent record of the fluctuations of temperature over 24 hours. An additional indicator may be situated, for example, in the works manager's office, where the temperature may be observed, in addition to the dial adjoining the stereo pot.

Electrical pyrometers are available using one indicator

for any number of melting-pots up to twelve; by using this multi-station arrangement a substantial saving in cost is effected.

With a modern printing plant of large capacity an efficient pyrometer is certainly advisable and is an economy.

The 'paper test'. The old-fashioned paper test provides but a rough-and-ready means of judging casting temperatures; if it is to be helpful, the conditions must be kept uniform by using the same sort of paper and immersing it for the same period each test. The change in colour of the paper gives an approximate indication of the temperature, but it will be appreciated that the usefulness of the method depends upon the experience and judgement of the operator.

MELTING METALS ON COMPOSING MACHINES

Electric heating. Electric heating has clear advantages for composing machines. The temperature is readily controlled; modern immersion heaters localize the heat within the pot and the atmosphere in the composing room is healthier and pleasanter because fumes are not given off by the heaters.

Printing metals should be melted as quickly as possible so that the separated crystals are rapidly taken into solution. The rating of the heaters must be sufficiently large to ensure this. There will then be ample heating capacity in hand to provide quick recovery of temperature should the pot be chilled for any reason, for example by the addition of new metal.

Automatic ingot feeders. In composing machines, it is important:

- (a) To keep the molten metal at a uniform level in the melting-pot, the level varying slightly with different machines.
- (b) To add small quantities of metal regularly so as to avoid sudden temperature fluctuations.

These objects are achieved by the use of automatic ingot feeders which also save the operators' time and attention in feeding and watching the pot. There is the additional advantage of a measure of preheating of the metal.

Automatic feeders are recommended and in conjunction with thermostatically controlled pots assist in improving and standardizing production.

HYGIENE IN THE PRINTING WORKS

ALL reported cases of lead poisoning among printers can definitely be said to be due to the inhalation or breathing in of either dust or fume containing small particles of lead. Handling of type metal and fresh type is harmless.

The stereotyper and foundry worker are liable to get lead poisoning while drossing the molten metal or from careless dumping of the dross on the floor and the subsequent sweeping up and bagging operations.

The above is an authorized extract from the report by Sir Thomas Legge, Senior Medical Inspector of Factories.

Fortunately, cases of lead poisoning amongst workers in the printing industry today are rare, thanks principally to improved equipment and standards of cleanliness.

Prevention. Dross should not be dumped on the floor but should be kept in covered receptacles from the moment it is skimmed from the pots until it leaves the works; thus the foundry is kept clean and there is no lead dross to inhale and danger is averted.

Patent dross containers enable the dross skimmed from the molten metal to be placed directly into covered receptacles with automatically closing lids. The container itself can be sealed when full for collection by the local metal foundry. It is emptied in the smelting works and the empty container is returned.

This and other precautions are strongly urged in the

recommendations of the Joint Industrial Council of the Printing and Allied Trades of Great Britain and Ireland:

The contents of the filled dross container should not be transferred to any larger receptacle if danger from dust is to be avoided. It is highly dangerous and uneconomical for any attempt to be made to extract further metal from the dross by re-melting. This should be forbidden and the dross container sent direct to a metal refiner who has special reverberatory furnaces for the purpose. The fine dust left after re-melting is very poisonous.

The shelves, ledges, and floors of the room should be cleaned regularly by means of a vacuum cleaner and the dust collected transferred into water and passed down a drain.

It is in the interest of everyone to see that ventilating arrangements are as complete as possible for the carrying away of dust and fumes in the foundry and stereo department at the point at which they are produced, and that proper trays are in place under Linotype and Monotype casting machines and circular saws.

The dust in type cases should always be extracted by means of a vacuum-type cleaner—never by bellows or other device.

Plungers should never be wire-brushed in the open shop—dust-proof plunger cleaners now being available.

The operator, by keeping himself physically fit, can do much towards making himself more resistant to lead poisoning. He should pay scrupulous attention to cleanliness of hands and teeth. The hands should always be washed thoroughly before eating and drinking and when leaving work, and the teeth carefully cleaned and brushed at least twice a day. The importance of the care of the teeth in endeavouring to maintain a satisfactory standard of general good health cannot be too strongly emphasized.

THE METALLURGY OF PRINTING METALS

THE constitution and structure of printing metals have been discussed briefly on pp. 14–20. For the reader who wishes to study the subject more deeply, a fuller description is given below.

Condition of liquid metal. Alloys of tin, antimony, and lead when fully molten form homogeneous solutions.

Structure of solid metal. When an alloy solidifies, three things may happen:

1. The constituent metals may remain as a solution in the solid state (termed a 'solid solution').
The composition of a solid solution may vary within definite limits.
2. The metals may form a compound. Intermetallic compounds have a fixed composition and a fixed melting-point.
3. The metals may form a eutectic. This has a fixed composition and melting-point, but is a mixture of two or more constituents.

Frequently, two or more such changes may occur in the same alloy and when a printing metal solidifies, all three occur. Solidification is therefore a complex process.

Cooling curves. A great deal can be learned about the nature of alloys by studying the rate of cooling from the liquid to the solid state. In its simplest form, this investigation consists in melting a sample of the metal in a crucible and then allowing it to cool slowly while accurate readings of the temperature are taken at regular intervals, say every 30

seconds. The results are plotted on a graph which is called a cooling curve.

Latent heat. To melt a metal, it is not enough to raise the temperature to its melting-point; extra heat is required to transform it from the solid to the liquid state.

Conversely, when a metal solidifies it gives out a corresponding amount of heat which is known as the latent heat of solidification.

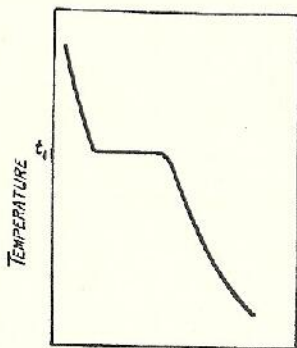


FIG. 22

This evolution of heat temporarily balances and arrests the rate of cooling.

Thus the solidification of a metal is indicated by an arrest point on the cooling curve.

Fig. 22 represents an ideal cooling curve of a single pure metal, such as lead. Observation starts when the metal is completely liquid. Cooling proceeds at a uniform rate until the temperature t_1 is reached, when the cooling is arrested owing to the evolution of latent heat. The temperature remains constant at t_1 until all the metal is solid, when cooling proceeds uniformly as before.

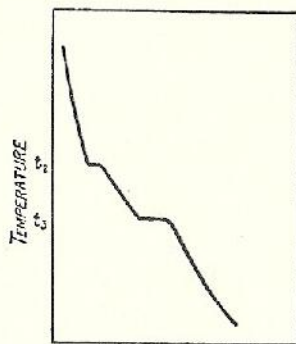


FIG. 23

Fig. 23 represents the cooling curve of an alloy made by adding a small quantity of antimony to pure lead. Two features will be noted:

1. The first arrest, at temperature t_2 , is below the freezing-point of pure lead. At this temperature (the 'liquidus') lead crystals start to freeze out of solution.
2. At t_3 , the temperature remains constant until the alloy has set completely. This arrest (the 'solidus') is caused by the solidification of the eutectic.

By taking cooling curves on a series of alloys covering the whole system and by plotting the arrest temperatures, a diagram is obtained which shows the liquidus and solidus temperatures for all the alloys in the series.

Antimony-lead alloys. Antimony and lead are completely soluble in each other in the liquid state and for present consideration may be regarded as mutually insoluble in the solid state.

The constitution diagram of the alloys of antimony and lead is shown in Fig. 24. The base of this diagram is divided so as to represent all the alloys of the two metals between 100% lead, 0% antimony, and 100% antimony, 0% lead.

The vertical scale is temperature. Thus any point on the diagram represents a specific alloy of the two metals at a particular temperature, e.g. the point *X* represents an alloy of 40% antimony, 60% lead at a temperature of 1,000° F.

The freezing-points of pure lead (621° F.) and of pure antimony (1,167° F.) are included in their respective positions. The line *MEN* is the liquidus line of the system. Any point above this line (e.g. *X*) represents an alloy in the molten condition.

The system has a eutectic (*E*) with the composition 12% antimony, 88% lead, which freezes at 486° F. All the alloys

finally freeze at this temperature, as indicated by the horizontal solidus line *OER*. Any point below this line represents an alloy in a wholly solid condition.

It is customary and convenient to denote the constituents which separate by Greek letters. Alloys containing more than 12% antimony on cooling first deposit crystals of antimony,

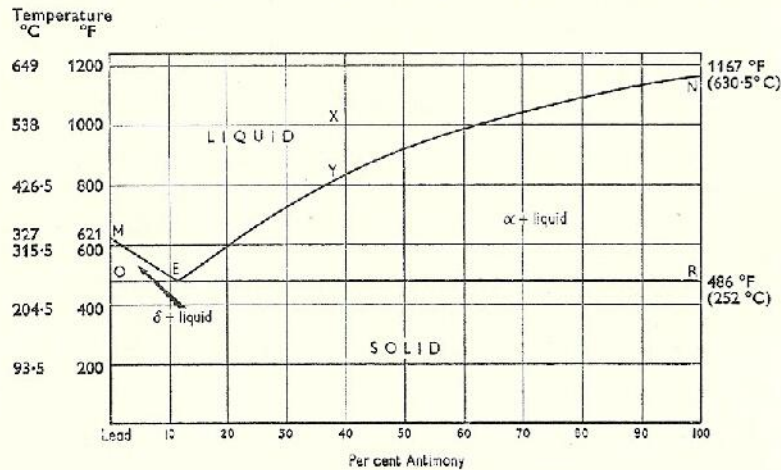


FIG. 24. Lead-antimony alloys

denoted by α . Thus the alloy containing 40% antimony, 60% lead, on cooling from 1,000° F. (point *X*) remains liquid until the point *Y* is reached. Then α antimony crystals form and grow until the temperature reaches 486° F. Since solid antimony crystallizes out of the liquid metal, the latter gets progressively richer in lead. By the time the temperature has fallen to 486° F., the liquid metal contains only 12% antimony—the eutectic proportion—and it then solidifies.

Tin-antimony alloys. The system tin-antimony (Fig. 25) is a complex one but it gives a guide to the ways in which tin modifies the structure of lead-antimony alloys.

The liquidus line *TCRA* has three branches. The solidus is *TDFBPOA*. At the antimony rich end, the α constituent can contain up to 11% of tin in solid solution. The α solid solution differs little from pure antimony in characteristics.

Alloys containing between 58 and 90% of antimony first deposit crystals of α on cooling from the liquid, but when the temperature reaches 797° F. (line *RPO*) a reaction occurs

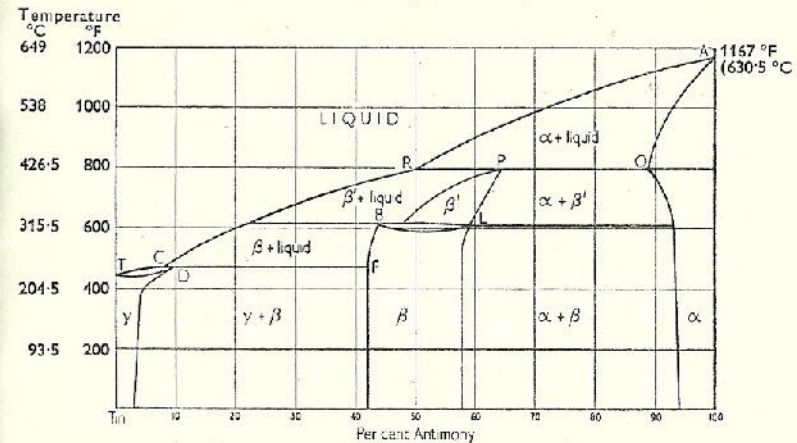


FIG. 25. Tin-antimony alloys

which results in some of the α changing to the β constituent. The solid alloys consist of a mixture of the two constituents.

The pure β constituent is formed from alloys containing 42 to 58% of tin. It is substantially the intermetallic compound tin-antimony (50% tin, 50% antimony) with small amounts of tin or antimony in solid solution. The intermediate compound β' which is shown on the diagram is purely of theoretical importance; on cooling it changes to β as the result of a rearrangement of the atomic structure.

To summarize:

Antimony-rich alloys in the solid state consist of α solid

solution. Alloys containing between 42 and 58% of tin consist of β solid solution. Alloys in between these two ranges consist of a mixture of α and β constituents.

The ternary system, tin-antimony-lead. The above diagrams show the constitutions of alloys in the binary systems at different temperatures. Matters become more complicated when the system contains three metals. It is not possible to depict completely in one diagram the effects of changes in both composition and temperature.

In order to express the composition of all alloys containing the three metals, it becomes necessary to use a triangular diagram (Fig. 26). Each corner of the triangle represents one of the pure metals. Each side of the triangle represents the compositions of alloys containing two only of the metals. Each point within the triangle represents an alloy containing all three metals.

The diagram is divided into areas according to the nature of the constituents which are first to crystallize when the alloys cool from the liquid state. The constituents which are present in printing metals are

- (a) δ solid solution consisting substantially of lead.
- (b) α antimony-rich solid solution.
- (c) β solid solution based on the tin-antimony compound, 50% tin, 50% antimony.

The lead-rich corner of this diagram, which covers printing metals, is shown enlarged in Fig. 27. Here a series of 'contour' lines enable the liquidus temperature of any alloy to be found.

If the contours are followed from B representing pure lead to X , it will be seen that the liquidus temperature falls. In other words, the addition of antimony and tin to lead reduces the liquidus temperature. The alloys in this range deposit crystals of lead (δ) in the initial stages of solidification.

X is the ternary eutectic point, having the lowest liquidus temperature of the alloys within the field.

From X to the line AD , the liquidus temperatures rise again, steeply, as shown by the closeness of the contours. These are

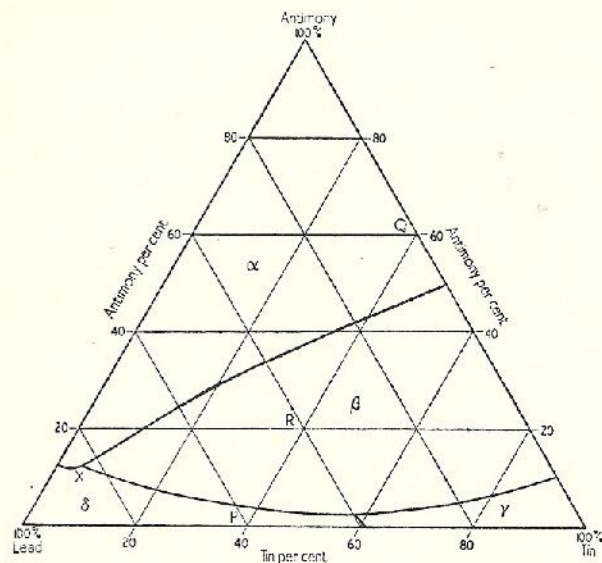


FIG. 26. Tin-antimony-lead alloys

The composition of any alloy containing all three metals is indicated on a triangular diagram. Thus the line PQ represents all the alloys which contain 40% of tin. The point R represents the alloy containing 40% tin, 20% antimony, the balance being lead. The point X represents the alloy containing 4% tin, 12% antimony, 84% lead

antimony-rich alloys, depositing α solid solution on solidifying.

In the field XGF , the rise in liquidus temperature from X towards HH is much more gentle. The diagram thus shows that the melting-point is increased much less when tin and antimony are added together than when antimony is added alone.

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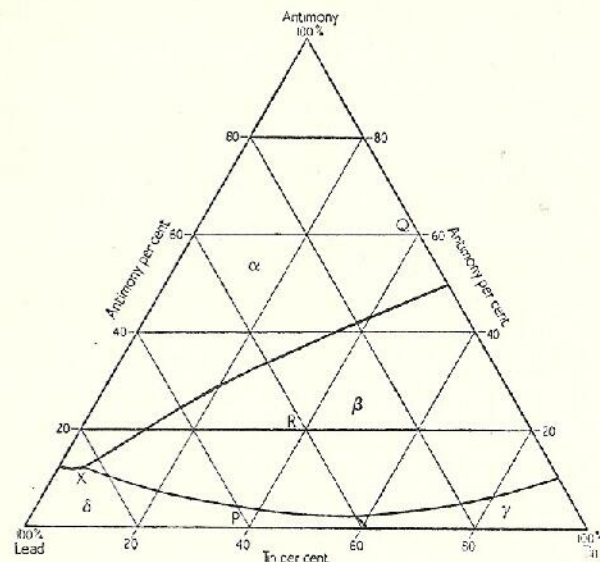


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In the field XGF , the rise in liquidus temperature from X towards FH is much more gentle. The diagram thus shows that the melting-point is increased much less when tin and antimony are added together than when antimony is added alone.

Alloys in this field first deposit the hard β tin-antimony crystals when they solidify.

The ternary diagram thus gives a good deal of information about the primary crystallization of the alloys. It does not indicate the last constituent to solidify—but in printing metals this is always the same, the ternary eutectic. It has been explained that, in lead-antimony alloys free from tin, the eutectic is an intimate mixture of fine crystals of lead and antimony. The ternary eutectic is similar in nature but more complex. It has the approximate composition of X —4% tin, 12% antimony, 84% lead, and is a finely divided mixture of the three phases enumerated above— α , β , and δ .

The ternary eutectic is the final constituent to solidify in virtually all the alloys above the line BH in the diagram.

DIAGRAM OF
FIRST FREEZING-POINTS
TIN-ANTIMONY-
LEAD ALLOYS

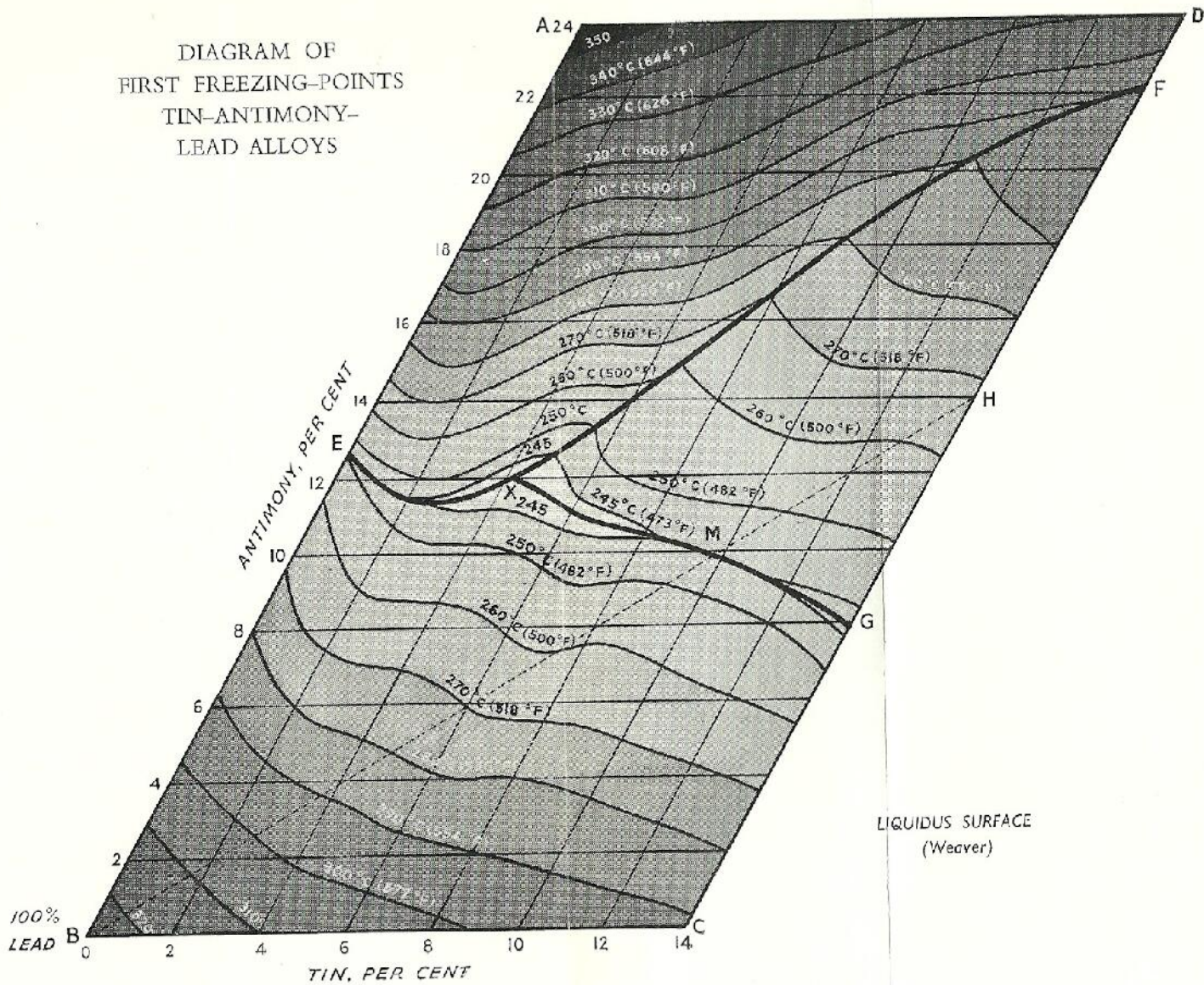


FIG. 27

APPENDIX II

METHODS OF PHYSICAL EXAMINATION

Preparation of specimens for microscopic examination. When specimens are examined microscopically any irregularities or scratches present in the surface are multiplied by the magnification employed. It is essential therefore that the surface should be both flat and highly polished. After filing the specimen to remove saw marks and to obtain a reasonably flat surface, it is rubbed on successively finer grades of emery paper placed on a sheet of plate glass to maintain a flat surface. Paraffin oil is used as a lubricant and to wash away the metal particles. The last grade of emery paper (3/0) produces a fine matt surface. Final polishing is carried out using metal polish on a pad of Selvyt cloth. The resulting surface should be flat and mirror bright.

In order to bring out the contrast between the constituents the specimen is etched in a suitable reagent. A solution of 5% silver nitrate in water is normally used. This reagent darkens the lead-rich phase, but leaves the other phases white.

Measurement of hardness. The hardness of printing metals is usually measured on a Brinell machine and the hardness quoted as the Brinell Hardness Number (B.H.N.). In this method a hardened steel ball is pressed into the surface of the metal under a given load for a set length of time producing a saucer-shaped depression. A load of 500 kgm. applied to a 10-mm. ball for 15 seconds is suitable.

The Brinell Hardness Number =
$$\frac{\text{load}}{\text{spherical area of impression}}$$

Density and percentage of voids. The density of printing metals is calculated using the well-known Archimedes principle. The metal is weighed first in air and then suspended in

water; the difference in weight, in grammes, is equal to the volume of the specimen, in cubic centimetres. The density, in grammes per cubic centimetre, is obtained by dividing the weight by the volume.

To determine the percentage of voids in a piece of type, the density of the type itself is first measured by the above method. The type is then melted and cast into a button which is quite solid; the density of the button is measured. The percentage of voids is obtained from the formula:

$$\text{Voids} = \left(1 - \frac{D_T}{D_M}\right) 100\%$$

where D_T is the density of the type and D_M is the density of the metal.

METHODS OF ANALYSIS

'Wet' method. The determination of the proportions of tin and antimony in a type metal is generally made by a 'wet' method. Fine sawings or filings are taken from the prepared sample of metal in such a way that they accurately represent the whole of the sample. Acid is then added to a weighed quantity of these sawings or filings so that the metal is converted into chlorides. These chlorides are oxidized by the addition of standard solutions of potassium permanganate (for the antimony content) and iodine (for the tin content), the end points being ascertained by the change in colour of the solution. A simple calculation shows the amounts of tin and antimony in the original sample.

Absorptiometer. Copper is generally determined by dissolving a weighed quantity of the prepared sample and adding a reagent which will selectively develop a 'copper-colour', the depth of which is measured by an absorptiometer.

Spectrograph. Impurities are detected and determined by means of a spectrograph. The sample is cast into electrodes and vaporized by an arc or high tension spark. The emitted light is split by means of a prism into a characteristic spectrum, which is photographically recorded and examined.

X-ray fluorescent Spectrometer. Of recent years there have been developments in the analysis of metal samples by the X-ray fluorescent spectrometer. This provides a rapid alternative to the 'wet' method of analysis of the major constituents. The sample is subjected to the emission from an X-ray tube which causes a secondary fluorescent radiation. The measurements of wavelength and intensity of this radiation provide data for the identification and determination of the percentage of the various elements present in the sample.

APPENDIX IV
LIQUIDUS TEMPERATURES OF
TIN-ANTIMONY-LEAD ALLOYS

Antimony %		Tin %					
		2	4	6	8	10	12
2	°F.	585	568	561	556	550	543
	°C.	307	298	294	291	288	284
4	°F.	559	545	540	536	529	522
	°C.	293	285	282	280	276	272
6	°F.	536	527	518	514	511	504
	°C.	280	275	270	268	266	262
8	°F.	513	507	498	495	491	482
	°C.	267	264	259	257	255	250
10	°F.	491	485	478	477	475	478
	°C.	255	252	248	247	246	248
12	°F.	482	463	477	485	489	493
	°C.	250	239	247	252	254	256
14	°F.	516	498	495	500	507	511
	°C.	269	259	257	260	264	266
16	°F.	550	531	527	514	525	531
	°C.	288	277	275	268	274	277
18	°F.	577	565	559	536	540	547
	°C.	303	296	293	280	282	286
20	°F.	604	601	590	565	552	558
	°C.	318	316	310	296	289	292
22	°F.	637	626	615	597	585	579
	°C.	336	330	324	314	307	304
24	°F.	662	646	635	626	612	608
	°C.	350	341	335	330	322	320

The data on melting temperatures in this book and the diagram, between pp. 82 and 83, are due to Miss Frances D. Weaver, Ph.D. (Mrs. Harold Heywood).

The results of her investigation into the lead-antimony-tin system were published in the *Journal of the Institute of Metals*, vol. lvi, No. 1, 1935.

APPENDIX V
SOME PHYSICAL PROPERTIES OF A
PRINTING METAL

10% tin, 15% antimony, 75% lead

Shrinkage on solidification: 2.0% by volume.

Thermal expansion: 0.000011 inches per inch per °F.
0.00002 inches per inch per °C.

Specific heat: 0.038.

Latent heat of fusion: 47.16 B.T.U.'s per lb.

26.2 calories per gramme.

Thermal conductivity: 0.057 calories/sq. cm./cm./°C./sec.

Electrical conductivity: 6% of conductivity of standard copper.

Tensile strength: 4.2 tons per square inch.

661.57 kilogrammes per square centimetre.

Elongation: 2%.

Density: 0.354 lb. per cubic inch.

9.78 grammes per cubic centimetre.

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