PRINTING METALS

THEIR PRODUCTION NATURE AND USE

By

MEMBERS OF

CAPPER PASS & SON LTD

and

PASS PRINTING METALS (LONDON) LTD

MANUFACTURERS OF HIGH GRADE PRINTING METALS

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PREFACE TO FIRST EDITION

THIS book has been compiled for the benefit of all those engaged in the Art of Printing, including Managers, Foremen and Operators, who are interested in the production, nature and use of Printing Metals.

That it will prove a concise and valuable source of information is the hope of

CAPPER PASS & SON LTD.

PREFACE TO FOURTH EDITION

SOME eleven thousand copies of this book are now in circulation throughout the world. Its scope was considerably enlarged in the Third Edition and the Authors have pleasure in acknowledging their indebtedness to Messrs. Intertype Ltd., Messrs. Linotype & Machinery Ltd., Messrs. The Monotype Corporation Ltd., and Messrs. Martin J. Slattery Ltd., for permission to use certain information given in the respective Composing Machine Handbooks concerning the production of slugs and type. The present edition contains some new material, including notes on electro backing metals.

CAPPER PASS & SON LTD. *and*
PASS PRINTING METALS (LONDON) LTD.

IT is the Authors' desire that everyone concerned with the casting of Printing Metals shall have a copy of this book for personal use. Copies can be obtained by applying to

PASS PRINTING METALS (LONDON) LTD.,
Forum House,
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London, E.C.3.

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CHAPTER I

THE METALLURGY OF TIN, ANTIMONY AND LEAD

METALLURGY is the science of extracting metals from their ores and their preparation for various uses.

With certain rare exceptions, metals are not found in Nature in the metallic state. They occur as minerals, that is, chemical compounds of the metals with oxygen, sulphur, carbonic acid, silicic acid, phosphoric acid, etc., and these compounds are termed "ores."

The first operation, therefore, is to "mine" the ore, that is, to dig it out from the earth's crust and bring it to the surface.

The ore, as mined, is contaminated with many times its weight of valueless rocky or earthy matter called "gangue," and as much as possible of the gangue must be separated from the valuable ore by suitable treatment. This process is termed "Concentration," and usually consists of crushing, grinding and washing with a stream of water. In some cases, however, other methods are employed, such as oil flotation, acid extraction or heat treatment.

The concentrated ore is now handed to the

Smelter, whose business it is to extract the metal in the metallic state, and to separate it from various metallic and non-metallic impurities always present in the ore.

The ore is generally subjected to a preliminary treatment, such as calcining or roasting; sintering or partial fusion; extraction with acid, etc. This treatment either removes some of the impurities present, or renders the ore more suitable for the actual smelting operation. Sometimes the treatment is applied for both these reasons.

To convert the metal in the ore into the metallic state, the prepared ore is mixed with suitable fluxes, reagents and carbonaceous material, and the mixture heated to the requisite temperature (a white heat in the case of Tin) in a furnace which may be either a blast furnace or a reverberatory furnace.

In the case of a blast furnace, the charge and fuel are put in together at the top of the furnace, and a blast of air is blown into the furnace near the bottom to support the combustion of the fuel; but in the case of a reverberatory furnace, the charge is put by itself on the "hearth" of the furnace, while the fuel is burnt in an adjacent fireplace, and the charge is melted by the heat from the fuel being reflected or "reverberated" from the crown of the furnace.

In both cases the result is the same, the charge being converted into slag (a glass-like product) and metal. These are run out of the furnace in a fluid condition and collected separately.

The metal obtained from the smelting furnace, whether blast or reverberatory, is still very impure and has to be subjected to various refining processes to remove the remaining impurities.

Tin. Tin occurs in Nature as the mineral Cassiterite, also called Tinstone or Black Tin, which is a compound of Tin and oxygen. Cassiterite is mined in Malaya, Dutch East Indies, Bolivia, China, Siam, Nigeria, Australia, Cornwall and Burmah.

The ores produced in Malaya, Dutch East Indies, China and Australia are smelted on the spot, and the Tin comes into commerce as Straits Tin, Banca Tin, Chinese Tin or Mount Bischoff Tin respectively.

The bulk of all the other ores is smelted in England, this country having the second largest Tin smelting capacity in the world.

The purest Tin in the world obtainable on a commercial scale is " CHEMPUR " Tin, smelted and refined by Capper Pass & Son Ltd. " CHEMPUR " Tin is 99.99 per cent. pure, and has been adopted as the standard of Tin in various Government Departments, Universities and Testing Laboratories all over the world.

Tin is white in colour, but not as bright as

Silver, and tarnishes very slowly in the air.

It is very soft and malleable, and can be rolled into thinner sheets than Lead, owing to its greater tenacity.

Specific Gravity, 7.29.

Melting Point, 449.6°F. (232°C.)

All the brands of Tin accepted as "Standard" Tin on the London Metal Exchange exceed 99.75 per cent. of Tin. These are reasonably pure, but some of the Tin sold as "Lamb & Flag" quality, also known as "English Common Tin," is barely 99 per cent. of Tin, and contains various deleterious impurities, such as Iron, Copper, Arsenic, Bismuth, etc.

Antimony. Antimony is obtained from an ore called Stibnite, a compound of Antimony and Sulphur, which is mainly found and smelted in China. However, the purest Antimony in commerce is refined in England. The Stibnite is concentrated and purified either by liquation (that is to say, melting away the Stibnite from its less fusible gangue by a careful application of heat) or else by volatilization.

Metallic Antimony is highly crystalline and brittle. It has a white colour, with a brilliant lustre, and does not tarnish readily in the air. It expands slightly at the moment of solidification.

Specific Gravity, 6.71.

Melting Point, 1166°F. (630°C.)

Antimony is a difficult metal to purify. There are a few brands which exceed 99.5 per cent. of Antimony, and these command a special price. Much of the Antimony on the market is very impure, the principal impurities being Arsenic, Zinc and Sulphur.

Lead. Lead is produced mainly in the U.S.A., Mexico, Canada, Australia, Spain, Burmah and Rhodesia.

The principal ore of Lead is Galena, a compound of Lead and Sulphur, and is generally found in association with Zinc Blende (a compound of Zinc and Sulphur), and usually contains sufficient Silver to pay for its extraction.

The Oil Flotation process is most generally used in the concentration of Lead Ore, since it is the only effective method of separating the Lead Ore from the Zinc Ore.

Metallic Lead is very soft and malleable, but with low tenacity. A freshly-cut surface has a bluish-white colour, and tarnishes rapidly in the air.

Specific Gravity, 11.37.

Melting Point, 621°F. (327°C.)

Lead of a high degree of purity can be obtained in commerce, and in the best brands the impurities are negligible. Outside of these brands care is required, as odd parcels of Lead are sometimes contaminated with Zinc and other impurities.

CHAPTER II

THE NATURE OF PRINTING METALS

THIS chapter, mainly theoretical in character, gives in a simple manner an account of the internal changes which occur during the heating and cooling of Printing Metals and of the microscopic structure produced in them under different conditions.

A knowledge of these matters is necessary to understand what occurs when these alloys are used in practice, but it is not essential to the carrying out of the practical instructions given in Chapters III and IV.

It is customary in practice to refer to the alloys used for Printing purposes as metals; but a sharp distinction must be drawn between "metals" in this sense of the word and true elementary metals. A true metal contains one constituent only—the individual metals Lead, Tin and Antimony may be taken as examples—while a "mixed metal" containing two or more constituents should, strictly speaking, be described as an "alloy." Thus, Printing Metals are alloys of Tin, Antimony and Lead, and it is important that this fact should be borne in mind, since the behaviour of Printing Metals is very largely determined by their composition. The proportions of the three constituents of Printing Metals vary according to the grade of the metal, whether Linotype, Stereotype or Monotype, and the whole range of Printing Metals is covered by the following limits of composition :—

Tin	2 per cent. to 20 per cent.
Antimony ..	10 per cent. to 30 per cent.
Lead	The balance.

While it is true in a general way that each of the constituent metals does impart some of its own characteristics to an alloy, yet an alloy is *not* by any means merely a mechanical mixture exhibiting the average characteristics of its constituents. It is a new body having its own individual character.

As an example, the behaviour of alloys of Lead and Antimony on melting and on solidifying may be considered. A pure metal, such as Lead or Antimony, when heated melts at one definite temperature, and when the molten metal is cooled it solidifies or " freezes " at the same definite temperature. This temperature is referred to either as the Melting Point or Freezing Point of the metal.

The Melting Point (or Freezing Point) of Lead is 621°F., that of Antimony is 1166°F. If we now consider an alloy of Lead and Antimony, the case is not so simple. When the alloy is heated a proportion of it melts at 475°F., and the alloy softens; but melting is not complete until a higher temperature, which depends upon the composition of the alloy, is reached.

Conversely, on cooling the molten alloy, solid metal begins to separate out at a definite temperature for each alloy, but solidification is not complete until a lower temperature, which is the same as that at which melting began on heating (475°F.), is reached.

The temperature at which separation of solid metal begins on cooling the molten alloy, or at which melting is complete on heating the solid alloy, is known as the *Freezing Point* of the alloy.

The temperature at which melting begins on heating the solid alloy, or at which solidification is complete on cooling the liquid alloy, is known as the *Eutectic Temperature.*

Whatever the composition of the original alloy, the portion which melts at the Eutectic Temperature on heating, or which does not solidify until the Eutectic Temperature is reached on cooling, is found to contain 87 per cent. of Lead and 13 per cent. of Antimony. This alloy is known as the " Eutectic Alloy " of Lead and

Antimony. (The word "Eutectic" means "easily melting.")

If a series of alloys of Lead and Antimony is prepared with a gradually increasing proportion of Antimony, the Freezing Points of this series of alloys drop progressively below the Freezing Point of Lead as the quantity of Antimony increases up to the proportion of 13 per cent. of Antimony. As the quantity of Antimony is increased beyond 13 per cent., the Freezing Points rise progressively up to the Freezing Point of Antimony.

The Eutectic Alloy containing 87 per cent. of Lead and 13 per cent. of Antimony has the lowest Freezing Point of all the alloys of Lead and Antimony. It is also the only alloy of the series which melts at one definite temperature, any other alloy having a Melting Range extending from the Eutectic Temperature to the Freezing Point, within which range the alloy is partly fluid and partly solid.

The following Table illustrates by a few typical examples the manner in which the Freezing Point varies with the composition in the Lead-Antimony series of alloys :—

TABLE I.

FREEZING POINTS OF CERTAIN ALLOYS OF LEAD AND ANTIMONY.

Composition.		Freezing Point.	
Lead, per cent.	Antimony, per cent.	°F.	°C.
*100	—	621	327
95	5	554	290
90	10	500	260
*87	13	475	247
80	20	572	300
60	40	806	430
40	60	968	520
20	80	1076	580
*—	100	1166	630

In the above Table of Freezing Points it must be emphasized that only three substances melt at a definite temperature, viz., Pure Lead, Pure Antimony and the Eutectic Alloy. These three are marked with an *. All the alloys, except the Eutectic Alloy, have a Melting Range extending from the Eutectic Temperature to the Freezing Point.

To take another illustration of change of characteristics, Lead and Tin are both very soft metals, but the addition of 1 per cent. of Tin to Lead produces an alloy much harder than either of them.

In Printing Metals, speaking broadly, the Lead may be regarded as forming the body of the alloy. The Tin confers toughness, hardness and fluidity. The Antimony confers hardness, and its presence in the alloy has a very important influence on the volume change at the moment of solidification. Alloys of Tin and Lead and, in fact, the great majority of alloys, show a very marked contraction on solidification. Antimony expands on solidification, and the presence of Antimony in alloys of Tin and Lead counteracts their tendency to contract on solidification. Printing Metals then undergo no contraction on solidification. This is an essential property, enabling the metal to fill every corner of the mould or matrix, and giving the necessary sharpness to the smallest detail.

In the fully molten and mixed state, Printing Metals may be regarded as uniform mixtures of the three elementary metals—Tin, Antimony and Lead—but if the temperature of such a mixture is allowed to fall steadily, the mixture undergoes certain changes in constitution before it solidifies completely. Below a certain temperature—called the "Freezing Point" (often referred to as "Separation Temperature" in practice)—the elementary metals present in the mixture begin to form various metallic combinations with one another, which separate out in a solid state from the mixture. As the temperature falls still further increasing quantities of the constituents separate out in the solid state, until at last a temperature is reached at which all the remaining fluid portion solidifies. This temperature is called the "Eutectic Temperature," and the portion of the alloy which does not solidify until the Eutectic Temperature is reached is known as the "Eutectic alloy." Below the Eutectic Temperature the alloy is completely solid. (Compare the behaviour of alloys of Lead and Antimony, pages 17 and 18.)

From the above account it will be seen that there are three distinct stages during the slow cooling of a Molten Printing Metal.

First Stage.—The alloy is fully molten and of uniform composition as long as the temperature is above the Freezing Point.

Second Stage.—The alloy is partly solid and partly fluid when the temperature is below the Freezing Point but above the Eutectic Temperature. At this stage it is no longer uniform in composition, for the solid portion is of different composition from the fluid portion.

Third Stage.—The alloy is entirely solid when the temperature is below the Eutectic Temperature, and its physical structure is complex.

It is very necessary to grasp the fact that Printing Metals do not freeze or become solid at one definite temperature, but that they solidify gradually over a certain range of temperature, during which period they are partly fluid and partly solid, the two portions being of quite different composition and properties.

The only exceptions to this statement are the Eutectic Alloys, which are the mixtures having the lowest Freezing Points in a series, and these Eutectic Alloys do pass directly from a fluid to a solid state at one definite temperature; but so far these alloys have not been found useful as Printing Metals.

In the practical use of Printing Metals the Second Stage referred to above is what might be termed the dangerous stage, for, as will now be realized, when the alloy is passing through this stage it separates into portions having very diverse compositions and properties, and rapid cooling is called for, so as to pass into the Third Stage as quickly as possible, for the rate at which a Printing Metal cools has a very considerable effect on the resultant physical structure of the solid alloy.

A microscope is of great help in studying the nature of Printing Metals. In preparing a Printing Metal for examination under the microscope, a small ingot of the metal is cast, which is then cut in half by means of a hack-saw, and the cut surface is ground flat and polished to a mirror-like smoothness. The small, smooth-surfaced piece of metal thus obtained is known as a " section " of the metal. The section is etched by putting it in a liquid which attacks certain components more vigorously than others, thus rendering the various components clearly visible when the surface of the section is examined under a microscope. If desired, a camera may be used in conjunction with the microscope, and photographs taken to serve as a permanent record of the appearance of the magnified surface.

If such a section through the final solid alloy is examined under a high-powered microscope, the separations which occurred during the Second Stage are clearly visible, the constituents which separated first being seen embedded in the mass of Eutectic Alloy, which is the portion that solidifies last of all. The full development of this physical structure is dependent upon the rate of cooling being sufficiently slow to allow of the separations taking place, but however quick the cooling, the separation always takes place to a certain extent.

If the rate of cooling is very rapid, such as is obtained by water cooling in a small mould, then the growth of the separated constituents is checked, and the physical structure is rendered more minute. See Figs. 1 and 2.

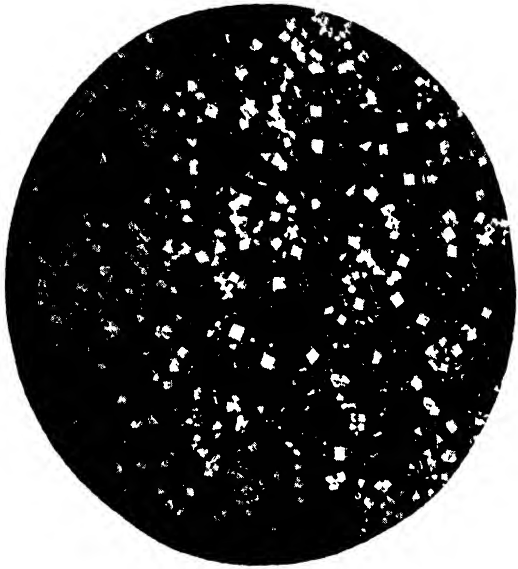


FIG. 1.

Photomicrograph (magnification 150). Polished and etched section of a small ingot, *quickly* cooled, of a Printing Metal containing 8 per cent. of Tin, 17 per cent. of Antimony, 75 per cent. of Lead. Note the large number of small cubical crystals of a compound of Tin and Antimony which are evenly distributed over the whole section.

The physical structure shown in this photograph is that which exists in a well-made type or stereoplate, and may be regarded as the "ideal."

FIG. 2.

Photomicrograph (magnification 150). Polished and etched section of a small ingot, *slowly* cooled, of a Printing Metal containing 8 per cent. of Tin, 17 per cent. of Antimony, 75 per cent. of Lead. Note the small number of large cubical crystals of a compound of Tin and Antimony which have risen towards the upper part of the section, leaving the lower part practically free from crystals. In this case the internal changes which occur during the *Second Stage* of the cooling of a Printing Metal (see pp. 19 and 20) have had ample time for their development, so that the Tin-Antimony crystals have grown to a large size, and have risen towards the upper surface of the metal. The physical structure shown in this photograph is coarse and not uniform. It would be quite unsuitable for type or stereoplates.

The effect upon the physical structure of Printing Metals of the rate of cooling is visible to the naked eye in the appearance of the fracture of the alloy. The fracture of the slowly-cooled Printing Metal shows a very coarse grain, often with large crystals, whereas the fracture of the rapidly-cooled Printing Metal shows a fine uniform grain.

The great difference in the fracture produced by variations in the rate of cooling is often not sufficiently realized by those who use Printing Metals, and consequently false deductions are made as to the composition, purity or mixing of the metal. Nevertheless, the examination by an expert of a fracture produced under certain known conditions of casting and cooling can yield much information on these three points.

From a Printer's standpoint a metal with a fine fracture (rapidly cooled) is preferable, as it melts more readily. It must not be thought, however, that a metal with a coarse fracture *due to slow cooling* is "bad" or "spoilt," for it only requires heating for a little longer time to become thoroughly molten. Then, if rapidly cooled, its structure and fracture will become fine and granular.

The examples of *slow* cooling mentioned in this chapter are given because they demonstrate very clearly the nature of the internal changes which occur in Printing Metals in actual use, and

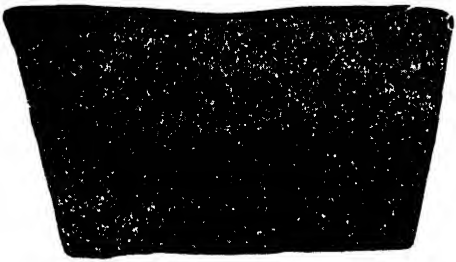


FIG. 3.

Figure 3 shows the fracture of a small ingot of Monotype Metal containing 10 per cent. of Tin and 15 per cent. of Antimony. This metal was *quickly* cooled, and shows a very fine uniform structure, such as should be found in good type or stereoplates. Even in this case one darker patch will be seen which is somewhat richer in Lead than the remainder of the metal; but for reasons which will be described later it is practically impossible to secure absolute uniformity of structure. Still, the metal illustrated does show a very good type of working structure.

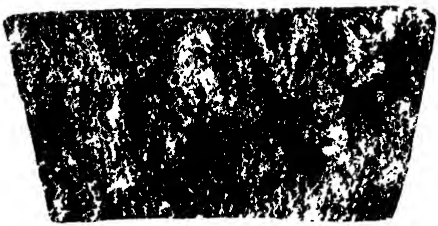


FIG. 4.

Figure 4 shows the fracture of a small ingot of metal of the same composition as that shown in Figure 3, only, in this case, the metal was cooled *slowly*. It will be noticed how coarse the fracture is, and what a large crystal growth there has been. A fracture of this kind should never be found in type or stereoplates. The alloy, however, has not been "spoilt" by slow cooling. If it is melted up, and then recast and cooled quickly, a fine granular structure will be restored.

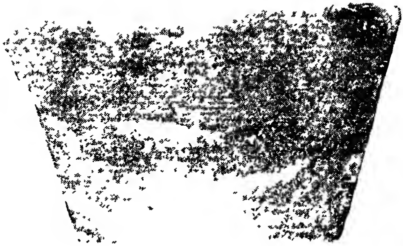


FIG. 5.

Figure 5 shows a section through a notch of Printing Metal containing 8 per cent. of Tin and 17 per cent. of Antimony. In this case the metal was *quickly* cooled. The notch was sawn in half, the surface ground flat, polished and, finally, etched. Two long patches will be observed which are rather rich in Lead. Apart from that, the section shows a very fine uniform structure.

FIG. 6.

Figure 6 shows the section through a notch of Printing Metal containing 8 per cent. of Tin and 17 per cent. of Antimony. In this case the metal was *slowly* cooled. A great difference in structure between the upper and the lower part of the ingot will be observed, the reason for which will be explained later, and also a large pipe-hole will be noticed. The formation of this pipe-hole was due to the fact that the upper part, sides and bottom of the ingot solidified first, and the still molten liquid in the centre, as it continued to cool, contracted, so that when its turn came to set there was not enough of it left to fill the whole of the space. It must be emphasized at this point that, while at the actual moment of solidification there is no contraction in the case of a Printing Metal, the *molten* Printing Metal does contract during cooling down to the point of solidification.

emphasize the need for *quick* cooling in casting ingots, type, slugs or stereoplates. In actual practice *quick* cooling is the rule, owing primarily to the requirements of speed, so that the likelihood of slow cooling occurring is small; but even when the metal is quickly cooled the changes occur to a limited extent, and must be reckoned with.

The following photomicrographs will give some idea of the structure of Printing Metals. These are prepared by taking photographs of polished and etched sections magnified by means of a microscope, as described above.

Figs. 7-11 illustrate the appearance of sections of various Printing Metals when magnified 150 times, all the Printing Metals having been quickly cooled, and showing ideal working structures. In every case the Tin-Antimony component, whether occurring in the form of definite crystals or in a very finely-divided form as part of the background, shows white, while the Lead shows black. In every case, except that of the metal illustrated in Fig. 7, part of the Tin and Antimony has separated out in the form of numerous small crystals, but on account of the quickness of solidification these crystals have not had time to coalesce, and so the structure has remained minute.

The hardness of a Printing Metal depends upon the amount of crystalline Tin-Antimony compo-

FIG. 7.

Figure 7 shows the section of a Linotype Metal, containing 2 per cent. of Tin and 12 per cent. of Antimony. The Tin-Antimony component is seen in a very finely-divided form as white points or filaments, while black patches of Lead free from Tin and Antimony may be observed.

Fig. 8.

Figure 8 shows the section of a Stereotype Metal containing 4 per cent. of Tin and 14 per cent. of Antimony. Numerous small crystals, which consist of Antimony holding about 10 per cent. of Tin in solution (see p. 45), will be seen distributed over the section, while in the background finely-divided Tin-Antimony component will be noticed along with the Lead.

FIG. 9.

Figure 9 shows the section of a Monotype Metal containing 6 per cent. of Tin and 15 per cent. of Antimony. Numerous small but well-formed cubes will be noticed. These consist of, approximately, 50 per cent. of Tin and 50 per cent. of Antimony (see page 45). Finely-divided Tin-Antimony component will again be seen in the background.

FIG. 10.

Figure 10 shows the section of a Monotype Metal containing 8 per cent. of Tin and 17 per cent. of Antimony. The structure here is very similar to that seen in the last section, except that the crystals are more numerous.

FIG. 11.

Figure 11 shows the section of a Monotype Display Metal containing 10 per cent. of Tin and 25 per cent. of Antimony. The cubes are rather larger than in the previous section, and they occupy a larger proportion of the section. The greater size of the crystals is accounted for by the fact that this metal does not set quite so quickly as the previous one, and so there is a longer time for the coalescence of particles or, in other words, for crystal growth.

nent present, and so it will be seen that the metals which have just been considered increase progressively in hardness, starting with a soft Linotype Metal free from crystals and finishing with a very hard Monotype Display Metal containing numerous well-formed crystals.

For comparison with the sections which have just been described, a series of sections will now be considered which show the structure of metals slowly cooled over a period of some hours. Slow cooling has resulted in the metals remaining for a long time in the partly liquid, partly solid stage (see page 20), and so solid particles which separated out early have had ample opportunity to coalesce, and in all cases except that of Linotype Metal considerable crystal growth of the Tin-Antimony component has occurred. All the sections are shown at the same magnification as in the previous series, viz. 150 times.

It must be emphasized that the structures illustrated in the case of slowly-cooled ingots are quite unsuitable for type or stereoplates, on account of their coarseness and lack of uniformity; but they are of interest as showing the form which the various components assume when they are allowed to develop. For good working structures, quick cooling with consequent suppression of the growth of the components, resulting in minute, uniform structures, is essential.

Fig. 12.

Figure 12 shows the section of a Linotype Metal containing 2 per cent. of Tin and 12 per cent. of Antimony. The ingot was *slowly* cooled, and the section gives an idea of the structure of a Eutectic Alloy in the presence of excess of Lead. The Eutectic Alloy consists of very fine filaments of the Tin-Antimony component alternating with equally fine filaments of Lead, the whole forming a closely-knit pattern. The black patches in the section are Lead, while the presence of a few larger white particles of the Tin-Antimony component is due to the fact that the cooling, slow as it was, was not sufficiently slow for the metal to assume completely its most stable structure. Had the cooling been infinitely slow, all the Tin-Antimony would have passed into the finely-divided form seen in the Eutectic Alloy.

FIG. 13.

Figure 13 shows a point in the upper part of a *slowly* cooled ingot of Stereotype Metal containing 4 per cent. of Tin and 14 per cent. of Antimony. Elongated crystals of Antimony holding 10 per cent. of Tin in solution (see p. 45) are seen, while Eutectic structure will be noticed in the background.

FIG. 14.

Figure 14 shows a point rather lower on the same section as that illustrated in Figure 13. It illustrates the portion of the ingot intermediate between the upper part in which the crystals are collected and the lower part which is free from crystals and consists of Eutectic Alloy only. Hollow crystals filled in with Eutectic structure will be seen.

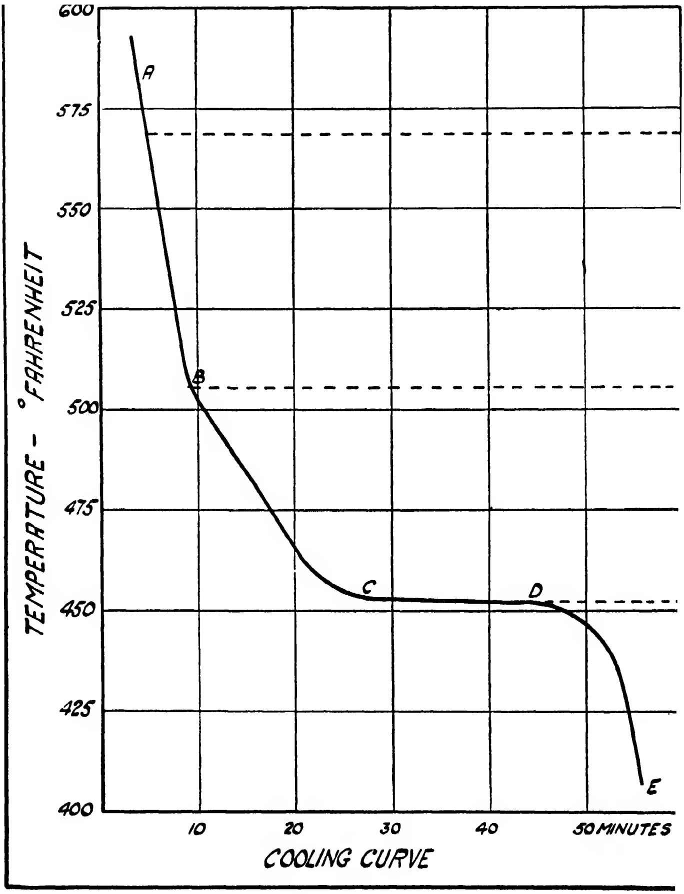
FIG. 15.

Figure 15 shows a point in the section of a *slowly* cooled Monotype Metal containing 8 per cent. of Tin and 17 per cent. of Antimony, the point being on the dividing-line between the upper part of the ingot, in which the cubical crystals containing 50 per cent. of Tin and 50 per cent. of Antimony have collected, and the lower part of the ingot, which is free from crystals and consists of Eutectic Alloy only.

In order to make more clear the physical changes that occur during cooling of an alloy from its fully molten stage to its completely solid stage, it will be helpful to describe what is known as the Thermal Method of Investigation. The most common form of procedure is to take a convenient amount of metal, say about 10 lbs., heat it in a crucible until it is fully molten, then surround the crucible with a non-conducting material such as asbestos, place a suitable thermometer in the metal, and allow the whole to cool slowly. During cooling readings of the thermometer are taken at convenient equal intervals of time, say once every minute. When the whole operation is over, and the metal has set solid, the readings are plotted on a curve, temperatures being shown on the vertical axis and time on the horizontal axis. Such a curve is known as a " Cooling Curve."

A Cooling Curve typical of Printing Metals and a great many other alloys is shown in Fig. 16, together with a simple interpretation, and this will now be considered in detail.

It is found that at first a smooth curve is obtained corresponding to the cooling of the fully molten metal. At a certain point (B) there is a sharp change in direction of the curve. The curve continues in its new direction for some



600
575
550
525
500
475
450
425
400
TEMPERATURE - °FAHRENHEIT
A
B
C
D
E
10
20
30
40
50 MINUTES
COOLING CURVE

FIG. 16.

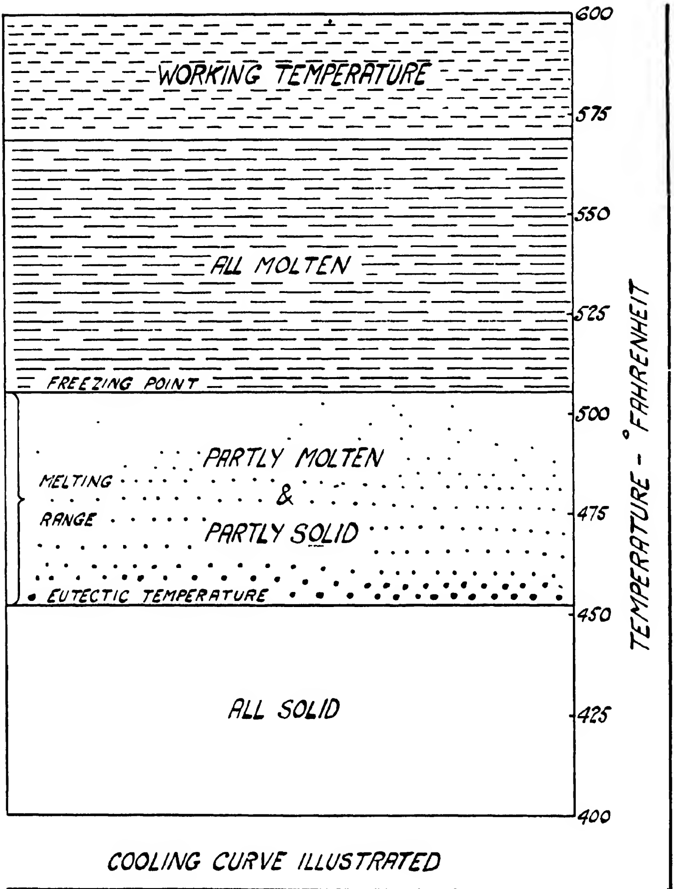

WORKING TEMPERATURE
ALL MOLTEN
FREEZING POINT
MELTING RANGE
PARTLY MOLTEN & PARTLY SOLID
EUTECTIC TEMPERATURE
ALL SOLID
600
575
550
525
500
475
450
425
400
TEMPERATURE - °FAHRENHEIT
COOLING CURVE ILLUSTRATED

FIG. 16.

time; then there is another sharp break (C), and the curve runs horizontally for a certain length of time. After this there is a third break (D), and the curve continues again as a smooth curve, though in a different direction from the first portion A-B. To explain a curve of this nature in terms of the physical changes which occur during cooling of a metal from the fully molten state to the solid state, it must be mentioned that separation of solid from the molten metal begins at a certain definite temperature for each alloy. When this occurs heat is liberated, and the rate of cooling is checked (Point B). As the temperature continues to fall more solid separates, and the metal goes through a pasty stage. The separation of solid continues until at another temperature, which also is a definite temperature for each alloy, the whole of the remaining liquid portion of the alloy solidifies without further fall of temperature (Line CD). The remainder of the curve (DE) corresponds to the cooling of the completely solid alloy. The first break (B) in the curve corresponds to the first separation of solid from the molten liquid. The temperature at which this occurs is known as the "Freezing Point" (in practice generally called "Separation Point") of the alloy. The temperature at which all the remaining liquid portion of the alloy solidifies corresponds to the horizontal part of the curve, and is known as the "Eutectic Point."

A Eutectic Alloy may be defined as the alloy which has the lowest Freezing Point of all the alloys of any particular series of metals, and is the only one that solidifies at one fixed and definite temperature. We have already given an example of this in considering the Lead-Antimony alloys, as described on pages 17 and 18.

In the case of pure metals and Eutectic Alloys, the terms "Melting Point" and "Freezing Point" may be used indifferently, since each substance of this nature melts at one definite temperature on heating, and solidifies at the same definite temperature on cooling from the molten state, but this is not so in the case of Printing Metals; they are not Eutectic Alloys, and melt over a range of temperature instead of at one definite temperature, and conversely solidify over a range of temperature when cooled from the molten state. It is obvious that a Printing Metal must not be used unless it is in the fully molten state, *i.e.*, it must be at a temperature above the Freezing Point, which is the upper limit of the Melting Range, and in practice it is advisable that the working temperature should be at least 50°F. above the Freezing Point.

The Melting Ranges of some typical Printing Metals are given in the following Table:—

Composition.		Class of Metal.	Melting Range, Fahrenheit.
Tin, per cent.	Antimony, per cent.		
2·4	11·8	Lino	463°—469°
3·5	11·5	Lino	459°—475°
6·4	15·8	Mono	457°—502°
7·2	14·2	Stereo	459°—493°
8·2	17·2	Mono, Stereo	455°—525°
10·2	16·2	Mono, Stereo	460°—520°
10·2	25·2	Mono Display	455°—602°

In the above Table the lower temperature given opposite each metal is the temperature at which the alloy *begins* to melt, while the higher temperature is that at which the alloy is *just* completely molten. Thus, at temperatures below the lower temperature given the alloy is entirely solid; at temperatures above the higher temperature given the alloy is entirely fluid, while between these two temperatures the alloy is partly solid and partly fluid.

These temperatures must not be confused with working temperatures, which are given on page 53.

In the case of Monotype Metals and Stereotype Metals holding more than 4 per cent. of Tin, as soon as the molten metal cools below the Freezing Point some of the Tin and Antimony in the alloy will combine in nearly equal proportions, separating out in the solid state as cubical crystals. (See Figs. 9, 10, 11 and 15.) These cubical crystals have a very low Specific Gravity as compared with the still fluid portion of the metal, and they therefore rise very rapidly to the surface of the metal, rather like corks in water, and form a pasty or "sandy" layer. This pasty layer, very rich in Tin and Antimony, represents the "cream" of the metal. If it is skimmed off, a soft leady metal, low in Tin and Antimony, is left behind. The Tin-Antimony crystals are very hard and, by themselves, would require a very high temperature to *melt* them. Fortunately, however, they are readily *soluble* in the more fluid portion of the Printing Metal at a temperature of 730°/750°F.

In the case of Stereotype Metals holding less than 4 per cent. of Tin, when the molten metal cools below the Freezing Point, the first substance to separate out into the solid state is Antimony holding a certain amount of Tin in solid solution. The proportion of Tin in this *solid solution* never exceeds 10 per cent., as compared with 50 per cent. in the Tin-Antimony cubical crystals described above. Apart from this, the behaviour is very similar to that already described. (See Figs. 8 and 13.)

In the case of the majority of Linotype metals, when the molten metal cools below the Freezing Point, the first substance to separate is Lead, which sinks to the bottom of the pot. The Lead readily melts again when the temperature is raised above the Freezing Point.

From the foregoing remarks it is apparent that the importance of working at the correct temperature can hardly be over-estimated. In the following chapter certain limits of temperature for different classes of Printing Metals are given; but the best temperature within these limits, in any particular case, must be determined individually.

For example, if the temperature of the metal in the pot of a Monotype machine drops below the lower permissible limit, then the hard Tin-Antimony crystals begin to separate out in the jet, causing choking of the jet and resulting in imperfect type.

On the other hand, if the temperature of the metal rises above the upper permissible limit, then trouble is caused by "splashing," blistered type, burnt matrices, etc.

THE TERM "VIRGIN METAL" AS A DEGREE OF QUALITY*

The term "Virgin Metal" is used by many printing houses who stipulate that the alloys they use must be made from virgin metal, meaning, of course, Tin, Lead and Antimony, which qualified by the term "virgin" satisfies them that they will receive alloys of the highest degree

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of purity. Unfortunately, meanings have been given to the term which are far beyond its proper definition. As a result it is inadvertently used with an entirely wrong sense by many whose knowledge of metallurgy is small; and intentionally used in the same way by some vendors of metals and alloys.

The difficulty arises chiefly because the expression has no *exact* metallurgical meaning, and therefore each person using it ascribes his own meaning to it.

So far as the expression is properly used, it seems to carry two implications, namely:—

(1) That the metal has not been used in the service of man since being smelted.

(2) That the metal is of a high degree of purity.

This definition, therefore, excludes remelted metal, and metal not of the highest purity; but even so, the expression "virgin metals" is often applied to remelted and reconditioned alloys (such as printing metals), also to certain elementary metals, such as "common" Tin, "Lamb and Flag" Tin, Chinese Antimony, etc., which are often very impure.

There is grave danger in using these remelted alloys, or impure metals, because certain of the impurities, often present, cannot be eliminated without a proper smelting operation, followed by a series of refining operations.

The term "smelting" is applied to certain high temperature metallurgical operations, which are carried out in either blast furnaces or reverberatory furnaces, in which the metalliferous ores, residues, drosses, slags, etc., are brought into contact with the appropriate fluxes and reagents to convert the desired metal, or metals, into the metallic state, and to separate it from the impurities associated with it. The metal obtained in this manner has then to undergo further furnace operations, classified under the general term " refining," for the purpose of removing the remaining impurities.

Finally, the metal, or alloy, is subjected to a series of low temperature operations in so-called " pots " or " kettles," made of cast or wrought iron, and holding up to 50 tons of metal; but these low temperature operations must *follow a suitable* furnace treatment, and are in no way a substitute for it.

A metal, or alloy, which has merely been remelted and reconditioned, cannot correctly be called a " virgin " metal, or alloy, whereas a metal, or alloy, which has been obtained as the result of a properly conducted smelting and refining process is in the fullest sense a " virgin " metal, or alloy.

However, while the present ambiguity and confusion in the use of this expression persists, it is advisable for both producers and users of metals and alloys to avoid using it in their specifications.

There is also another expression often applied by printers to a printing metal, namely, "tired," which seems to be based upon a mistaken analogy with the so-called "fatigue," after long use of some of the ferrous metals.

The "fatigue" of ferrous metals is due to a change in the internal structure of the solid metal under the effect of continued strain and vibration, which results in the metal becoming crystalline and brittle. This condition may be entirely removed by suitable heat treatment, called "annealing," at a temperature much below the melting point of the metal.

Obviously, therefore, a printing metal does not become "fatigued" or "tired" in this sense, because each time it is melted the internal structure is reformed, and is dependent upon the conditions of casting and cooling.

No amount of remelting under proper conditions will "fatigue" or "tire" a metal, but in the case of an alloy or "mixed metal," the composition may undergo a change owing to one constituent being more volatile or oxidizable than another.

In the case of printing metals a change of composition, with consequent change in working properties, does occur in actual practice in three ways :—

(1) In remelting type, slugs or stereoplates a certain amount of unavoidable oxidation

occurs, and as Tin is more readily oxidized than Lead or Antimony, rather more Tin is lost in this way than of the other constituents and the printing metal gradually becomes impoverished in Tin.

(2) In drossing printing metal, which is at too low a temperature and not fully molten, a dross very rich in Tin and Antimony is taken off, leaving a leady metal unsuitable for its purpose. This loss is entirely avoidable if drossing is done in the proper way.

(3) By allowing printing metals of different compositions to be mixed together before remelting; the remedy for which is obvious.

Certain deleterious impurities, such as Copper and Zinc, are also often introduced into the printing metal by allowing copper shavings or brass rules to get into the melting pot, and completely spoil the metal.

Apart from these three points, there is no reason why printing metals should not be used over and over again, and indeed in any carefully run works they are so used, new metal being introduced only to make up for unavoidable wastage, or for increased business.

CHAPTER III

PRINTING METALS IN PRACTICE

THIS chapter deals with the practical side in two parts—first of all as concerns the general practice in the use of metals, and secondly the special application to their individual uses.

Printing Metals are alloys of Tin, Antimony and Lead, in varying proportions according to the particular conditions under which they are to be used.

Constituents and Properties. For any particular set of conditions it is important that the proportions of the three elementary metals are rightly chosen, for the composition of the Printing Metal determines its working properties.

Limits of Composition. In general, Printing Metals come within the following limits :—

Monotype Metal.

Tin ..	..	5 per cent. to 12 per cent.
Antimony	..	14 per cent. to 25 per cent.
Lead ..	..	81 per cent. to 63 per cent.

Stereotype Metal.

Tin ..	..	3 per cent. to 10 per cent.
Antimony	..	14 per cent. to 20 per cent.
Lead ..	..	83 per cent. to 70 per cent.

Intertype, Linotype and Ludlow Metal.

Tin ..	..	2 per cent. to 5 per cent.
Antimony	..	10 per cent. to 13 per cent.
Lead ..	..	88 per cent. to 82 per cent.

Purity Printing Metals must have a high degree of purity. That is to say, they must be as free as possible from anything other than the three essential elementary metals. Iron, Aluminium, Zinc and Sulphur must not be present at all, as they interfere seriously with the working properties of a Printing Metal. Copper, up to the proportion of 1 per cent., is occasionally a constituent of Printing Metals used for certain special purposes; but in general the Copper content should not exceed a figure of 0.15 per cent., since greater quantities than this render the metal less fluid, and hence necessitate a higher working temperature.

Appearance and Fracture. The surface of the ingots of Printing Metals should be clean, bright and free from dross. The fracture should be fine and granular. Metal with a fine and granular structure melts more readily than metal having a coarse structure.

Correct Working Temperature. Next in importance to using a suitable and satisfactory metal is the question of using it at the correct temperature.

A temperature that is too *low* results in the metal being imperfectly melted, producing a lack of fluidity, apparent "sandiness," or "drossiness," choking of the pump, ports and channels of the casting machine through which the molten metal flows, imperfect type faces, sinks, etc.

A temperature that is too *high* results in excessive wastage and deterioration of the metal, burning of the matrices, "splashing" in the casting machine, cokey-faced stereoplates, undue wear and tear on pots, pumps, etc.

The makers of the various type, slug and plate-casting machines give excellent advice on the correct working temperature (and other matters) in their instructional handbooks. This advice should be carefully studied and followed.

The following limits of working temperatures may be taken as a general guide for satisfactory results :—

Monotype Metal, between 650°F. and 720°F.

Stereotype Metal, between 550°F. and 650°F.

Linotype Metal and other slug-casting metal, between 520°F. and 565°F.

It is not possible to give the exact temperatures for working, as these vary, within the above limits, in each particular case, according to the composition of the Printing Metal in use, the individual machine, the speed of casting, the size of type, and other factors.

A Thermometer, Pyrometer, or some form of automatic temperature control is essential in order to regulate the temperature accurately. An instrument of this kind should be in constant use, in order to obviate stoppages due to unintentional temperature variations.

Cleanliness. The importance of cleanliness, in its widest sense, for the production of good type, slugs or plates, can hardly be overestimated. Melting-pots, machines, pumps, boxes, moulds, etc., should all be kept scrupulously clean.

Different grades of metal should be kept separate.

Brass, Copper, Zinc or Aluminium should never be brought near the melting-pots. They should be put into a special receptacle. Printing Metal which has become contaminated with any of these impurities must not be used; it should be disposed of to a Metal Smelter, as these impurities can only be removed effectively by re-smelting and subsequent refining.

Dross should not be allowed to lie about. It should be put straight into a covered tin or small drum, or other suitable container.

Melting and Drossing Mono Metal, Stereo Metal.

In melting and drossing Monotype or Stereotype Metal, heat the metal, without stirring, to a temperature between 730°F. and 750°F. and keep it at this temperature for 20 to 30 minutes. Then stir the metal well, so as to mix it thoroughly. The metal should then be entirely fluid, with a dry, powdery dross floating on top.

Carefully skim off the powdery dross, which should be practically free from metallic particles. The metal should then present a mirror-like surface, free from any appearance of frostiness.

A " dross stick " about 16 in. by 2 in. by $\frac{3}{8}$ in., made from a wooden box-lid, is a very efficient and convenient tool for removing the dross from the molten metal.

Melting and Drossing Lino Metal.

In melting and drossing Linotype and other slug casting Metal, heat the metal to between 550°F. and 600°F. and keep at this temperature for a few minutes, stir well and skim off the powdery dross.

Fluxes.

A small quantity of a suitable flux is very useful in melting and drossing type, slugs or old Printing Metals, as it facilitates the separation of metallic particles from the powdery dross and so reduces wastage.

Palm Oil, Tallow or Mutton Fat are very suitable fluxes, particularly if they are rancid.

To use.—Put a small piece of the flux on to the molten metal before drossing, gently move the dross about with the dross stick for a few minutes, in order to mix it thoroughly with the flux, and then skim off the dross. Sufficient flux should be used to " moisten " the whole of the dross.

Chilled Metal.

Never skim chilled metal. It should be noted that molten metal in a pot may become chilled, either

(*a*) As a whole, such as happens when the fuel supply is cut off, or reduced excessively; or

(*b*) Locally, such as happens when a current of cold air blows across the surface of the molten metal.

If molten metal is accidentally chilled, it must not be used until it has been fully melted as described above.

Casting into Ingots.

When old metal (type, slugs, stereos, leads, etc.) is to be re-melted for casting into ingots, melt and dross the metal as already described. Then allow the temperature of the metal to fall to its normal working temperature and pour or run into *cold* moulds.

This procedure will give ingots of clean metal with a fine grain, and will produce a minimum of dross.

Losses on Re-Melting. Losses on re-melting are approximately as follows :—

(1) Clean Metal in Ingots.
The loss is negligible.

(2) Stereoplates.
The loss is not more that 0.5 per cent. by weight.

(3) Linotype and other slugs.
The loss is not more than 0.5 per cent. by weight.

(4) Monotype Type.
12 point—about 2 per cent. by weight.
6 point—about 3 per cent. by weight.

Composition of Dross. The dross skimmed off always contains a slightly higher percentage of Tin than the metal in the pot. Generally, the Tin contents run between 1 per cent. and 2 per cent. higher, while the Antimony contents are practically the same as in the metal.

Maintaining Standard of Composition. The greatest difficulty with which a printer has to contend in standardizing metals and obtaining uniform printing results is due to the steady loss, small though it is, that occurs in the Tin content, and, to a very slight degree, in the Antimony content, every time the metal is melted. This is more particularly noticeable in re-melting type, slugs or plates for casting into ingots for further use in the various composing machines.

First of all, consider what losses take place on melting. The loss is, of course, entirely in dross, and the loss in that dross is two-fold :—

(1) There is the simple, straightforward loss by weight of the dross formed. This is a depreciation in the quantity of the metal, and is simply replaced by adding new metal of the same composition as the metal in use.

(2) All dross contains a slightly higher percentage of Tin than the metal from which the dross is formed, *e.g.*, if the composition of the metal is 8 per cent. Tin, the dross will contain 9-10 per cent. Tin, though it may be considerably higher if the metal has been melted and drossed in a careless way. Under the best conditions, it is reasonable to assume that

the dross contains 1 per cent. more Tin than the metal. Thus, there is an extra loss in the dross of an additional 1 per cent. of Tin.

The total loss (1) and (2) mentioned can be replaced by adding a quantity of new metal equivalent in weight to the dross removed; but this metal must contain the additional 1 per cent. Tin that is also lost in the dross. In the majority of works a satisfactory composition for the metal in circulation has already been established; and supposing this desired standard is 8 per cent. Tin, 16 per cent. Antimony, balance Lead, it is maintained by replacing loss by dross with a new metal containing 9 per cent. Tin, 16 per cent. Antimony, balance Lead, the extra 1 per cent. of Tin replacing the slight extra loss of Tin. This method is much superior to the usual method of adding reviving metals, which usually contain 20-30 per cent. Tin, 20-30 per cent. Antimony, balance Lead; as on account of the high Tin and Antimony contents very careful estimation must be made of the correct weight to be added, in order that the "reviving" process is not overdone. By the method of using new metal only slightly richer in Tin, the "reviving" process is constantly going on in the right proportion, and with no risk of spoiling the metal if too much be added. Also, it is not necessary to carry any stock of special reviving metals, which are always costly. Should it be found that the general run of metal in stock is not losing "tone," then this recommended method is already being carried out, and there is no need to consider a metal of higher Tin content.

Before applying this principle to the individual cases of Stereo, Lino or Mono metal, let us consider melting conditions.

The losses on re-melting have already been shown on page 57, from which it will be observed that a small quantity of dross is formed on the metal in the metal-pot of an Intertype, Linotype, Ludlow or Monotype machine, because the metal is kept in a molten state for a considerable period of time, and slow oxidation takes place on the surface of the molten metal.

Dross consists principally of the oxides of the metal due to the surface of the molten metal being in contact with the air, causing it to oxidise; also of any dust, dirt or ink that may be adhering to the metal or Stereoplates.

A dross that shows economical working and treatment of the metal should consist of nothing but a fine dry powder. If there are any metallics present in it, this shows wastage, and a considerable risk is run, because these metallics may be some or all of the rich Tin-Antimony crystals that rise to the surface of the metal when first melted, or when it is cooled below Freezing Point, as has already been explained in Chapter II.

The proper procedure has been explained on page 55.

The individual cases of the metals for the different casting machines will now be considered.

It is assumed that all metal stocks, due to old matter being broken down, are brought to the standard of composition in use, otherwise no system for keeping to standard can be relied upon to give satisfactory results, owing to the wide variations that occur. The ideal method of carrying out this initial standardizing would be to install a melting-pot able to contain at least 30 cwts. of metal, then collect together sufficient type to fill it, and make a melting from which a sample would be taken for analysis. From the result the correct weight and composition of metal to be added could be calculated in order to bring it up to the desired standard.

In many works it is not feasible to install such a large pot, and when the work is done on a small scale of 3-5 cwts. at a time, it is not feasible to keep the metal in the pot during the period taken for an analysis of any sample. Furthermore, the cost of such analysis would be considerably more per ton on account of the number of analyses necessary. If a larger melting-pot is not available, the better method will be to send the metal to a smelting firm for correction.

The case of metal for Stereo plates for newspaper work is the simplest and ideal form for keeping up a standard of composition. First it is necessary to decide what composition metal is required in the actual Stereo plates. Supposing the composition be 9 per cent. of Tin, 15 per cent. of Antimony, balance Lead, from the earlier remarks it will be realized that it is necessary to use a new metal containing about 10 per cent. of Tin, 15 per cent. of Antimony, balance Lead, and this new metal is added to make up the loss of weight by dross. In order to keep up the level of the metal in the pot, old Stereo plates are fed in periodically as new plates are being cast, and the dirt and ink introduced tends to increase the formation of dross.

By noting the amount of dross produced over a period, the quantity of new metal to be added per diem to replace this loss can be estimated. Let us suppose that this is 3 cwts. per diem. These 3 cwts. can be added ingot by ingot throughout the period of casting plates, or the whole 3 cwts. can be added at the beginning or end of the plate-casting period; it is only a question of leaving sufficient room in the pot to accommodate the extra metal. This addition will replace the dross lost, and thus keep the total tonnage of metal in use a constant one; also it will add the extra amount of Tin required due to the additional loss of Tin in the dross. If conditions are ideal, and the dross is never richer in Tin than the limit of 1 per cent. more than the Tin content of the metal, then the composition of the metal in the pot and plates will always be the same, viz. 9 per cent. of Tin, and the total quantity of metal in circulation will always be the same.

In practice it has been found that such ideal conditions often obtain, and if care is taken there is no reason why every newspaper office cannot obtain the same satisfactory results.

With an Intertype, Linotype or Ludlow installation in a newspaper office here again an almost ideal arrangement exists. Every day the machines cast a large quantity of slugs, which are constantly being re-melted in a melting-pot containing, say, 10 cwts. of metal. The total amount of dross produced at each melting is known, and thus the amount of new metal necessary to replace it can be added at each melting of the slugs. It is quite simple to standardize instructions that a fixed number of pounds of new metal are added to every potful of re-melted metal. Here again the composition of this new metal must be at least 1 per cent. higher in Tin than the standard of metal desired in the actual Linotype slug. Supposing the slug is to contain 3 per cent. Tin, then the new metal must contain not less than 4 per cent. Tin. In addition to the dross formed on melting up slugs, small quantities of metallic scum are removed from the machine pots, but as it is the general practice to return this, together with the trimmings from the slugs, to the foundry for re-melting with slugs, there is no need to take this apparent loss into account.

In dealing with Monotype metal, and indeed any installation where matter is set up and stored away, sometimes for several years, it is not so simple to standardize as in the case of a newspaper plant, where all the Stereo metal is in circulation. However, having brought all the Monotype metal to an agreed standard of, let us say, 6 per cent. of Tin and 15 per cent. of Antimony, it is recommended that two grades of new metal be used :—

(*a*) A metal containing 6 per cent. of Tin, 15 per cent. of Antimony, which is purchased whenever new metal is required. This is put direct through the casting machine.

(*b*) In order always to maintain this standard of 6 per cent. of Tin, 15 per cent. of Antimony, it is necessary to keep a supply of a richer metal containing 7 per cent. of Tin, 15 per cent. of Antimony, which must be added to every re-melting of type in sufficient quantity to replace the amount of dross removed. As previously explained, this can be estimated, and it must not be forgotten to include in this estimation the weight of dross skimmed direct from the machine pots.

Thus, casting may be done with re-melted metal which, due to the constant addition of the very dilute reviving metal (*b*), is always being kept up to the standard fixed of 6 per cent. of Tin, 15 per cent. of Antimony. If there be no re-melted metal available, or it is desired to use new metal, the new metal (*a*) can be used, which, being of the same composition as the re-melted metal, will maintain the standard of composition and will also not require any adjustment of the casting machine, as would be necessary to accommodate a richer composition.

The above method is the ideal, and with careful organization and supervision in the foundry it will work well.

Far too little attention is paid in many printing houses to the condition under which old type plates and slugs are re-melted. This work should be done by an experienced man fully conversant with the correct temperatures, etc. Temperature control in re-melting metal is just as important as with the casting machine, and every melting-pot should be provided with a reliable thermometer, or other means of temperature control.

The recommendations made in the preceding paragraphs are based on ideal conditions, and it will be found that they can be carried out in practice to a very large degree, especially in works restricted to a specific routine, such as newspaper and book production. The results of such standardization of composition will be shown by a greater output of mechanical composition, due to uniformity of casting conditions, causing less stoppages, and there is the additional advantage of uniformity in the hardness of type throughout each job.

CHAPTER IV

PRINTING METALS AND CASTING MACHINES

IN the following chapter some practical hints are given on the use of metal in the principal casting machines.

"MONOTYPE" CASTING MACHINES

The four important parts of the casting mechanism are tabulated below, with notes as to possible difficulties that may arise, due to incorrect functioning of the parts to which reference is made.

(1) *The Pump Body Valve, sometimes called the "Hat Valve."* This valve and its seating must be kept clean, and the valve should have a $\frac{1}{32}$ in. clear hole in its centre. The valve checks the return of the metal from the nozzle when the piston is rising, excepting for a small quantity which returns through the $\frac{1}{32}$ in. hole. But if this hole is too large insufficient metal will remain in the nozzle and metal channel, and defective type will result, owing to an insufficiency of metal

beneath the piston. On the other hand, if the hole is too small, or is choked with dross, too much metal remains in the nozzle, and stop casting is likely to result, due to the metal chilling at the nozzle point.

(2) *Pump Body Nozzle and Pump Body Channel.*—The nozzle should be drilled every week, whether it appears to require it or not. Do not drill the nozzle when it is hot, lest the drill should lose its temper. It is of the utmost importance that the nozzle is kept clean and free from dross. The accumulation of hard stuff in the nozzle is nearly always due to working the metal at too low a temperature, or to the metal having been temporarily chilled. The metal in the pot may be quite molten, but its temperature may be so near to the Freezing Point (Separation Temperature) that the Tin-Antimony crystals begin to separate and deposit in the jet. These crystals, being exceptionally hard, are difficult to remove, even by drilling. The remedy is, of course, to raise the temperature of the metal. The pump body also should be cleaned every week, and the drill run up the main channel until it can be seen at the nozzle end.

(3) *The Piston.*—This is now made in two sections, the piston end being separate from, and loose upon, the stem. The piston end is held to the stem by an adjustable screw, which should be adjusted so that the piston end has $\frac{1}{32}$ in. vertical play between its lower and upper seating on the stem. The diameter of the adjusting screw is less than the hole in the piston end, and the lower seating for the piston end is grooved. The action is: As the piston is forced down by spring pressure to make a cast, the shoulder on the piston stem presses on the upper seating of the piston end, thus preventing any metal returning to the melting pot. On the return stroke the piston stem first moves, and the piston end is raised by coming in contact with its lower seating. Metal is thus enabled to run down the centre of the piston end, to beneath the piston by way of the grooves in the lower seating. When once adjusted correctly, further adjustment is seldom necessary, but the grooves in the piston lower seating should be kept free of dross. When inserting the piston always skim away dross above the pump body, so that the

piston may enter clean metal, and not carry down dirt or dross with it.

The Production of Good Type. To be considered perfect, the type cast on a "Monotype" machine must possess the following attributes :—

(1) It must be quite solid, having the corners sharp, with solid, flat feet, and face sharp and well-defined ; it must be neither too soft nor too brittle.

(2) It must be square in all directions, exact to size, and must be a correct height from the foot to the face of the character. Of vital importance, governing the quality of the type produced, is the temperature of the metal and the adjustments of the pump connections. If those are in order, everything then depends upon the the attendant and the metal.

Imperfect type is generally caused by one of the following reasons :—

(1) Insufficient metal entering the pump body.

Remedy.—Give a little more vertical play to the piston end between its upper and lower seatings.

(2) The pump not pumping the metal up into the mould satisfactorily.

Remedy.—See that the piston end is clear, and that the grooves in the piston end lower seating are clear of dross and that the pump body channel, pump body valve and seating, nozzle, etc., are all clean and free from dross, to allow an easy flow for the metal. A considerable improvement in the face of type can sometimes be made by increasing the pressure of the piston spring, which can be done by its adjusting nut. This adjustment, however, must not be overdone, lest jerky running of the machine should arise, or too much pressure be put on the mould blade and adjacent parts of the mould body.

(3) The metal too cold, causing chilling in the nozzle, and preventing sufficient metal being pumped into the mould.

Remedy.—Raise the temperature of the metal, or should this already be as hot as advisable, reduce the quantity of cooling water flowing through the mould.

It is of the utmost importance that scrupulous cleanliness is observed in all parts of the machine.

Faulty type is generally the result of some restriction in the metal flow, as described above.

Stop Casting. This occurs when no metal reaches the mould, and may be due to any one of the following faults :—

(1) Metal too cold, or when first starting up mould may not have warmed up, thus chilling the nozzle.

(2) Piston not free in pump body, but hanging up after a very short stroke has been made—this due to a dirty piston.

(3) Too much or too little metal passing through the inlet to beneath the piston.

(4) The nozzle remaining against the mould too long, causing metal to chill at the nozzle point—this is remedied by an adjustment causing earlier descent of the pump body.

(5) The mould chilled by too much water.

(6) The hole in the nozzle or pump body valve closed with dross and dirt.

In general, it may be said that providing the metal is of correct quality, the production of satisfactory type depends upon correct adjustment of the pumping mechanism and absolute cleanliness of the metal channels, as well as the temperature of the metal, and the maintenance of these conditions is entirely in the hands of the operator.

Temperature *Temperature of Metal in Pot.*—For this there are two limits of temperature—the lower limit at which the machine will not cast, and the higher limit at which the metal is prone to squirt and the type likely to blister and burst. Between these limits lies the correct working temperature. The most suitable temperature is judged from the appearance and quality of the type produced. If the type has a frosted appearance and the corners are not well-defined, the temperature is too low; if, on the other hand, the type is very bright, but shows signs of blistering, the temperature is too high. The face of the character must be sharp and well-defined, every part of the outline showing clear and distinct. Speaking generally, the correct temperature of the metal in the melting-pot varies between 650°F./720°F. according to the composition of the metal, the size of type and the rate of casting. A thermometer may be used for noting the temperature, but some form of automatic temperature control should be fitted to the machine to maintain accurate temperature of the metal; this will obviate stoppages due to undesirable temperature variations.

Temperature of Mould.—This is variable, and no exact rule can be given that will answer all cases; it varies with different sizes of type, with the speed of casting, and also between individual machines. Briefly, it may be stated that the larger the size of type being cast, or the greater the quantity of metal that will be passing through the mould at a given time, the greater the flow of water required to keep the mould at the required heat. If it is too hot, the mould blade will hang up, or the cross block will bind.

Further Notes on Attention to Metal.

Melting and Drossing of Metal.—In melting and drossing metal in use on a "Monotype" caster, heat the metal, without stirring, to a temperature between 730°F./750°F. and keep it at this temperature for 20-30 minutes. Then stir the metal well, so as to mix it thoroughly. The metal should then be entirely fluid, with a dry, powdery dross floating on top.

Carefully skim off the powdery dross, which should be practically free from metallic particles. The metal will then present a mirror-like surface, free from any appearance of frostiness.

A "dross stick" about 16 in. by 2 in. by $\frac{3}{8}$ in. made from a wooden box-lid is a very efficient and convenient tool for removing the dross from the molten metal.

It is a good practice to dross the metal in the pot of a "Monotype" caster once only in the day, and to do that on first starting work in the morning.

The reasons for this are :—

(1) The metal has to be melted in any case.

(2) There is less tendency to do the drossing hurriedly or carelessly.

(3) The day's work is started with metal that is thoroughly molten and clean.

The operation should be carried out exactly as described in previous paragraphs; the metal should then be brought to the proper working temperature before starting to cast.

Never Skim Chilled Metal

It should be noted that molten metal in the pot may become chilled, either :—

(1) As a whole, such as happens when the fuel supply is cut off, or reduced excessively; or

(2) Locally, such as happens when a current of

cold air blows across the surface of the molten metal.

If molten metal is accidentally chilled, it must not be used until it has been restored to the required temperature.

THE INTERTYPE AND LINOTYPE MACHINES

The Production of Good Slugs. A good slug, besides being true to size and having a good, sharp and well-defined face, must be solid in the body and feet. The chief faults met with are :—

(*a*) *Hollow Slugs, or Hollow Walls, and Pitted Face.*—These faults are due to insufficient metal reaching the mould either on account of restriction in the metal passages and mouthpiece by dross or dirt, the plunger being dirty and not pumping a sufficient quantity of metal, or the temperature of the metal being too low, causing chilling in the mouthpiece.

Remedy.—See that all metal passageways and the holes in the mouthpiece are absolutely clean and free from dross, and that the plunger is clean. If chilling in the mouthpiece is occurring, raise the temperature of the mouthpiece heater, and if this does not effect a cure, raise the temperature of the metal in the pot.

Hollow slugs are also caused by the plunger spring being too weak, causing insufficient metal to be pumped into the mould. This spring can easily be tightened ; but care must be taken not to apply too much pressure, or a jerky action when casting will result.

One other point that may be contributing to hollow slugs is that due to continual movement and wear of the pot legs, the pot is then likely to fall too low and the mouthpiece holes to be other than centred when casting 5 or 6-point slugs. The mouthpiece holes should be " dead " central across the mould on this point size, and adjustment is easily remedied by the two compensating screws on the bearings of the pot. Occasionally hollow slugs are caused by an ill-fitting plunger, which instead of forcing the metal up through the mouthpiece to the mould creates what is known as a " back-flow " of metal over the plunger-well. A machine with this weakness can always be detected, as on lifting the lid of the pot the backward splashes are visible during casting. Sometimes the airrelease grooves of the mouthpiece become clogged, thus restricting the escape of air from the moulds, and therefore ingress of the metal to the mould.

(*b*) *Hollow Feet.*—Indefinite or badly-formed feet to the slugs are caused by the temperature of the metal being too high, not allowing the base of the slug to solidify before the mouthpiece breaks away from the mould.

Remedy.—Reduce the temperature of the mouthpiece-heater and, if necessary, the temperature of the metal in the melting-pot.

A further and aggravated stage of this will cause "stick in the mould," due to the ejector blade becoming fixed in the still semi-molten slug.

(*c*) *Splashing.*—This fault is mainly mechanical, due either to imperfect justification of a line before it reaches the casting position or to the faulty adjustment of the pot legs, and both faults are easily remedied.

The lack of a metal-tight lock-up between the metal-pot mouthpiece and the back of the mould will also cause splashing. This condition may be caused by failure to maintain sufficient heat at the pot mouthpiece, resulting in particles of metal solidifying round the mouthpiece holes and so preventing a perfect lock-up. A slight increase of the pot mouthpiece temperature is necessary to correct this trouble.

(*d*) *Imperfect Face.*—A frosty appearance on the face of the slug, although the feet appear to be quite sound, is caused by the metal being too cold.

Remedy.—Increase the heat of the mouthpiece-heater, and metal in pot if necessary.

Temperature Since every machine has its own best working temperature for a particular metal, we can only lay down general limits, which are between 520°F. and 560°F., according to the nature of the work and size of body. A higher temperature is required for casting small bodies than for large body sizes. As already pointed out, there are two heating units—that for the melting-pot proper and that for the throat. Slight adjustments can be made by varying the throat temperature; but the proper function of this is to keep the throat at such a temperature that metal will not chill in the holes of the mouthpiece.

THE LUDLOW MACHINE

The foregoing remarks regarding the Intertype and Linotype machines apply equally to the Ludlow machine, except that adjustments vary in certain details, *e.g.*, the pot seating is adjusted by means of the crucible swivel bracket.

Heating is by electricity or gas and the control should be adjusted to maintain a temperature of 550°F. to 565°F. Any good grade of slug-casting metal is suitable, the ideal composition being :—

Tin ..	..	3.5 per cent.
Antimony	..	11.5 per cent.
Lead ..	..	The balance.

STEREOTYPING

There are certain standard flaws in the finished plates that may occur with any of the methods used for casting plates, and as with most casting troubles, they are chiefly due to incorrect temperature conditions.

(*a*) "*Sinks.*"—These are caused by the too rapid chilling of the surface of the metal, so forming a skin. This skin is drawn in (forming a hollow or sunken surface) as the molten metal behind this skin cools and contracts. To avoid confusion, it must be emphasized that while the metal does contract during cooling in the molten state, it does not contract at all at the moment of solidification.

Remedy.—Raise the temperature of the metal, say 20°F., and see that the mould is not too cold.

(*b*) "*Cokey*" *Face.*—This is due to the metal being too hot and scorching the face of the flong, thus producing minute bubbles of gas, which collect in the face of the plate, causing the cokey or porous face.

Remedy.—Reduce the temperature by at least 50°F.

(*c*) *Porous Plates, due to Trapped Air Bubbles.*—One of the biggest difficulties in high-speed casting is to get rid of the air trapped in the mould when the metal is poured in. Time must be given to allow the trapped air to bubble up through the molten metal clear of the top of the printing face of the plate before the metal solidifies. Sometimes the metal solidifies too soon, and these air bubbles are trapped just in the top edge of the printing face, where they will cause the plate to give way at this point when under the pressure of the Rotary Presses. If the metal can be kept molten a second or so longer, these bubbles will have risen into the " pour " or " tang " of the plate, which is sawn off. Thus it will be seen again to be a matter of temperature.

Remedy.—Lengthen the time of cooling by increasing the temperature of the metal, or alternatively by cutting down the supply of cooling water, or if no water is circulated, then use a hotter mould. It is possible that the trouble is a mechanical one, in that the " head " of the metal in the " pour " is not of sufficient weight to assist in the rapid expulsion of air from the mould. It may or may not be possible to improve on this, according to the design of the casting-box. Another possible cause in the case of those machines which pump metal into the mould is that the pump piston is worn, and air gets entangled with the metal as it is being pumped into the mould; this is not a very likely cause, but such a case has been known.

(*d*) *Cupped or Hollow-Faced Letters.*—Sometimes the large flat surface letters when cast have a concave surface. This is due to the metal being too hot and scorching the flong, causing it to distort slightly, with the above effect.

Remedy.—Reduce the temperature of the metal by at least 50°F.

(*e*) *Half-Tones.*—It happens sometimes that half-tone blocks cannot be reproduced satisfactorily. Assuming that the impression on the flong is satisfactory, the difficulty lies in the metal failing to run into all the interstices of the screen, because it is too "sticky."

Remedy.—Raise the temperature considerably. Possibly the metal is deficient in Tin, and therefore insufficiently fluid. For half-tone work a minimum Tin content of 8 per cent. is recommended.

The above remedies apply equally to all methods of casting, both Flat and Rotary Plates.

CHAPTER V

ELECTRO-BACKING METAL

Although the alloys used for this purpose are not in the strict sense of the term Printing Metals, the following notes may prove useful.

Compositions vary within the following limits :—

Tin	0·5 per cent.	to	4 per cent.
Antimony ..	2·0 ,,	,,	4 ,,
Lead	97·5 ,,	,,	92 ,,

It is important to remember that the Antimony content must not exceed 4 per cent. ; if it is in excess of this figure it will be found difficult, if not impossible, to bind the backing metal satisfactorily on to the tinned copper shell. Moreover, an alloy holding Antimony 4 per cent. should also hold Tin 4 per cent. particularly if the plates have to be curved, otherwise the metal will prove too brittle to bend without the danger of cracking.

Alloys in general use vary within the above narrow limits ; if the metal is to be used for flat plates the following compositions will give good results :—

Tin 0·5 per cent., Antimony 2 per cent., Lead 97·5 per cent.

Tin 2·0 per cent., Antimony 3 per cent., Lead 95·0 per cent.

If, however, metal is required for curved plates :—

Tin 4·0 per cent., Antimony 4 per cent., Lead 92·0 per cent.

is recommended.

A high degree of purity is necessary in alloys used for this class of work. Where metal is used over and over again a certain amount of contamination from Copper is inevitable. It is advisable, therefore, to ask your metal supplier to make periodic assays in order to obviate trouble. Arsenic should not be present except in minute proportions.

The Melting Ranges of two typical alloys are given as follows :—

Composition. Tin, per cent.	Antimony, per cent.	Melting Range. Fahrenheit.
2.0	3.0	462°—572°
4.0	4.0	462°—548°

The Backing Metal should be poured at a temperature of 660°/700°F.

APPENDIX I

DEFINITIONS OF SOME METALLURGICAL TERMS

Eutectic Alloy. In the case of a great number of series of alloys there is one alloy in each series which melts at a lower temperature than any other alloy of the series, and which melts, moreover, at a fixed temperature, whereas all other alloys of the series melt over a range of temperature. Such an alloy is known as a "*Eutectic Alloy*" (eutectic=easily melting), and the temperature at which it melts is known as the "Eutectic Temperature" of the series.

Freezing Point. The Freezing Point of a pure metal is the temperature at which the liquid metal solidifies when cooled. The Freezing Point of an alloy is the temperature at which separation of solid first occurs when the molten alloy is cooled.

Melting Point. The Melting Point of a pure metal or of a Eutectic Alloy is the temperature at which the solid metal or Eutectic Alloy melts when heated, and is identical with the Freezing Point in the case of these substances. The term "Melting Point" is not used in the case of Printing Metals and other alloys which do not melt at a definite temperature.

Melting Range. In the case of Printing Metals and the great majority of alloys, when the solid alloy is heated, melting begins at the Eutectic Temperature, and is not complete until the Freezing Point is reached. The range of temperature over which melting occurs is called the "Melting Range" of the alloy.

APPENDIX II

FAHRENHEIT-CENTIGRADE CONVERSION TABLE

Degrees.		Degrees.		Degrees.	
Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.
520	271·1	605	318·3	690	365·6
525	273·9	610	321·1	695	368·3
530	276·7	615	323·9	700	371·1
535	279·4	620	326·7	705	373·9
540	282·2	625	329·4	710	376·7
545	285·0	630	332·2	715	379·4
550	287·8	635	335·0	720	382·2
555	290·6	640	337·8	725	385·0
560	293·3	645	340·6	730	387·8
565	296·1	650	343·4	735	390·6
570	298·9	655	346·1	740	393·3
575	301·7	660	348·9	745	396·1
580	304·4	665	351·7	750	398·9
585	307·2	670	354·4	755	401·7
590	310·0	675	357·2	760	404·4
595	312·8	680	360·0	765	407·2
600	315·6	685	362·8	770	410·0

APPENDIX III

SAMPLING OF PRINTING METALS

FROM time to time it is necessary or advisable for a Printer to take a sample from his metal for the purpose of having it assayed. If the sample is to represent truly the bulk, certain precautions must be observed.

The following methods of procedure are recommended :—

(1) *Metal in a Pot.*

Melt, stir and dross as described in paragraph " Melting and Drossing " on page 55, then take out some of the metal in a ladle and pour it into a small strip or button mould. The whole of the strip or button, weighing not less than 4 oz., should be sent to the assayer.

(2) *Intertype, Linotype, Ludlow or Monotype Metal in use.*

Take a small handful (about 4 oz.) of the type or slugs from the machine.

(3) *Metal in Notched Ingots.*

Break off one or more *complete* notches.

(4) *Metal in Solid Ingots.*

Melt at least a whole ingot, or preferably several ingots chosen at random, and proceed as in Method 1.

(5) *Stereoplates, Old Type, etc.*

Melt in a pot, and proceed as in Method 1.

Owing to the separation which occurs in Printing Metals on solidification, an ingot or plate cannot, as a rule, be sampled by means of chipping, filing, drilling or sawing.

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