# Type metal alloys. 1927

Imperial Type Metal Co.
New York: Imperial Type Metal Co., 1927

# TYPE METAL ALLOYS

*Published by*

**Imperial**

**TYPE METAL COMPANY**

**NEW YORK PHILADELPHIA CHICAGO**

*Distributing Branches*

Albany
Atlanta
Baltimore
Birmingham
Boston
Buffalo
Cincinnati
Cleveland, Ohio
Columbus, Ohio
Dallas
Denver, Colo.
Des Moines
Detroit
Hartford, Conn.
Houston, Texas
Indianapolis, Ind.
Jacksonville, Fla.
Kansas City, Mo.
Little Rock, Ark.
Louisville
Memphis
Milwaukee, Wis.
Minneapolis-St. Paul
Nashville, Tenn.
New Orleans
Okahoma City
Omaha
Pittsburgh
Richmond
Rochester
San Antonio, Texas
St. Louis
Tampa
Tulsa, Okla.
Washington
Wichita, Kans.

Silver Buckle Press

# TYPE METAL ALLOYS

Linotype metal melts at
approx. 475°

*Published by*

Imperial
TYPE METAL COMPANY

NEW YORK PHILADELPHIA CHICAGO

*Distributing Branches*

Albany
Atlanta
Baltimore
Birmingham
Boston
Buffalo
Cincinnati
Cleveland, Ohio
Columbus, Ohio
Dallas
Denver, Colo.
Des Moines
Detroit
Hartford, Conn.
Houston, Texas
Indianapolis, Ind.
Jacksonville, Fla.
Kansas City, Mo.
Little Rock, Ark.
Louisville
Memphis
Milwaukee, Wis.
Minneapolis-St. Paul
Nashville, Tenn.
New Orleans
Okahoma City
Omaha
Pittsburgh
Richmond
Rochester
San Antonio, Texas
St. Louis
Tampa
Tulsa, Okla.
Washington
Wichita, Kans.

BEST BY ACID TEST

TRADE MARK REG.

# Contents

## Foreword

In the past publishers have been more or less handicapped in the solution of their type metal problems and students of journalism and printing halted in their quest for facts because the manufacturers did not deem it wise to let them know too much about their metal. As a result of this lack of knowledge many ideas of a superstitious character crept into their minds. Some of these ideas were purposely created and fostered by the manufacturers, though largely they were the result of inadequate knowledge of the nature of type alloys.

Realizing the obscurity and mystery that had been cast over the manufacture of type metal we determined, if possible, to lift the veil and present the problem in its true light, giving the users of type metal the results of our investigations and the information thus obtained. In this manner, we hope to establish a co-operative and mutual confidence with the consumers of type metal that will be a benefit to both the user and the manufacturer.

The publication of this book is, we believe, the first serious attempt at coordinating the many facts surrounding the use and care of type alloys.

Pamphlets have been issued from time to time, but they have usually been superficial and have not entered into the scientific side of the question. In order to carry out this work, it was necessary to thoroughly equip our laboratory not only for the general testing of all our products, but for the special work that these investigations required.

Our laboratory is always at the service of the publishers, for which service no charge is made, and the results are reported with the analysis of the sample.

Long ago the imperfections of the antiquated system of manufacture by "rule of thumb" rather than scientific precision were realized and were at once eliminated from our plants and the modern scientific method was adopted. The first step of advancement was the very careful chemical test of each heat before being cast into its respective form. This not only involved an analysis for tin, antimony, and lead, but the most thorough test for impurities of both a chemical and physical nature.

By careful research and study, it was found that the proper condition of the alloying could be detected with the aid of the microscope. Microscopes were therefore installed and became a permanent feature of our laboratory; the results of this application removing the last traces of doubt as to the quality of the alloys.

Another feature of our organization was the establishment of a drum service, which has revolutionized the whole field in the handling of dross. These drums were first installed by our company, for the shipment of dross. They are fitted with a removable head, thus making a fireproof, leakproof, easily-handled container.

In this volume, an attempt has been made to present the subject in such a form as to be serviceable and intelligible, not only to the scientific investigator and the students of our many printing schools, but especially to the publisher, for whom it was primarily written. If this volume fills the need of supplying more adequate information to the user of type metal, we have been well repaid for our efforts.

THE IMPERIAL TYPE METAL COMPANY.

## Type-Casting Machine Metal

The principal metals composing all alloys used in type-casting machines today are lead, antimony and tin. Although other metals are occasionally present they rarely exceed one per cent of the mixture, and are introduced only to slightly modify the main elements.

Lead is the base metal to which the other elements are added, and when properly compounded form an alloy indispensable to one of the largest and most widely distributed industries in the world. Lead is produced in large quantities in the United States, particularly in the Middle West. It is also produced in many other countries of both hemispheres.

Antimony is found only in very lean ore deposits in this country, and is therefore, almost exclusively an imported metal. English antimonies in former years ranked as superior in quality because of high purity and uniformity. By English antimony is usually meant antimony smelted and refined in England, but not made from English ore. Today, however, antimony is found in China and Mexico, the ores occurring abundantly in both of these countries. These countries have in the past usually undersold other producers, but their product has come to the front both in quality and price and has taken precedence over competitive brands in recent years.

The main impurities in antimony are arsenic, iron and copper, its value depending on its freedom from these elements. In the smelting of lead ores there occurs an impurity of antimony to be eliminated before soft lead can be produced. This antimony is closely associated with arsenic and the two are eliminated from lead at one operation, giving a by-product known as crude antimonial lead. This is a sluggish mixture containing varying percentages of antimony, lead, copper and arsenic. For many years it was almost worthless, but refining processes have recently made it of value in the production of certain alloys. It should never be used in making type metals, because of the impurities present, which are objectionable. However, some of the largest manufacturers use this material, because of its low cost, by diluting with purer materials.

Tin is one of the most valuable metals, both as to properties and cost. Its ores are not found in quantity in the United States, and therefore all tin is imported either as ore or in pigs. The best grades of tin are obtained from either the Straits Settlements or Banca. Some South American ores are now being smelted, but they are much inferior to the other ores mentioned.

## Function of the Three Elements

Lead alone is too soft, and lacks many of the valuable properties needed for type purposes. Therefore, the metallurgist has devised an alloy which is suitable, by adding antimony and tin in proper proportions, depending on the requirements of the service to be met.

Antimony when added to lead has the valuable and unusual property of imparting hardness to the metal and also increasing the fluidity of the molten alloy. A lead alloy containing antimony, due to fluidity has the property of filling out the type mould perfectly thus giving an exact reproduction of the mould. An alloy without antimony, but containing only tin and lead, as found in solder possesses none of the valuable typecasting properties of metal containing antimony. Next to antimony bismuth alone has this property but is prohibitive in price; so there is no feasible substitute for antimony.

Tin is the third and last principal element in type alloys, its purpose being frequently much confused with that of antimony. Tin does not reduce the melting point of the alloy, as is usually believed, when considering stereotype, line-slug and unitype metals. Type metals freeze at approximately 465° F. in all cases, whether tin is present or not. Tin does add very much to the fluidity of the alloy, however, and permits the work to be done *at much lower temperatures* and with much more perfect results. It is for this reason that it is often regarded as having reduced the melting point, whereas it has simply increased fluidity when molten, just as certain oils thin inks. Tin causes a much slower setting of the alloy, and too much, often becomes a detriment for this reason. This is occasionally noticed in line-slug machines where squirts and hollow slugs, through bleeding, follow an excess.

Tin gives body to the metal, adding considerably to its toughness. When in excess we notice an overcoming of the antimony properties and a return to the stringy properties of lead, which is harmful to saws, knife blades and ejectors in all type work. The remaining point worthy of mention, as a property of tin, is its ability to give to the type the smooth, perfect face, free from "cold shots." This means a better product and a type which will take ink properly and print perfectly.

The trade in general exaggerate the effect of tin percentage on length of run on press. This is largely due to sales arguments advanced by both the type foundries and metal houses in an attempt to establish the superiority of their product. The greatest secret of a long press run is a careful make-ready. The amount of change in hardness in metal produced by the addition of one per cent of tin or a change in composition of from four to five per cent of tin is not sufficient to make imperfect press room manipulation produce a perfect result on a long run and vice versa. Where a good make-ready, etc., is found, an alloy with little tin will seldom show undue wear or "batter." If this hardness was as noticeable as the trade is led to believe, we could approximate the tin percentage by an examination of physical properties of metal. This cannot be done, however, and only by chemical analysis can small changes in percentage of tin be determined.

## Eutectic Point

Lead, when pure, melts at 621° F.; antimony at 1166° F., and when 1 per cent of antimony is alloyed with 99 per cent lead the melting point is reduced to below 621° F. Two per cent of antimony causes a still further reduction, which continues, until the alloy contains approximately from 12 to 13 per cent antimony, balance lead, melting at 475° F. From this point on, by increasing antimony, the point of complete melting increases with each per cent instead of decreasing. Thus, we see that there is a certain percentage having the lowest melting point, which is approximately 12 per cent. This point is called the eutectic point, meaning point of lowest melting temperature.

## Impurities in Type Metals

Certain brands of antimony, tin and lead, because of their purity, command higher prices than others, although all are called new metal. All commercial brands of these metals, as smelted at the mines, contain some impurities, the removal of small traces of which is costly, *therefore the purity of the brand determines the selling price.*

Very few ores as taken from the earth contain 50 per cent pure metal, so the difficulty in separating the foreign metals to obtain a pure product can easily be imagined. For most purposes, purity is not exceptionally important, but in the case of metal alloyed for printing purposes purity is a vital question. This is because of the rigorous demand for a non-corrosive, free-flowing alloy that will operate successfully after repeated remelting. Hence the standard brands of lead, tin and antimony are not suited for type alloys until further purified by us and the highest possible degree of purity obtained.

Type metal consumers are often deliberately misled by talk of *virgin metals*, when the scientific valuation of the alloy is entirely a question of the purity and perfectness of alloying. *Virgin metal means nothing as to quality*, as the poor grades of tin, for instance, at a much lower cost, *are equally entitled to the term virgin*. The purity by acid test of its component parts is the absolute measure for determining the metal value both from the standpoint of cost and service.

The additional cost to remove the last traces of impurities is the reason that the issue is often clouded by the meaningless phrase, virgin metal, and a purity discussion left unmentioned.

The common impurities in lead, tin and antimony are copper, zinc, iron, arsenic and silver, all of which are present in considerable percentages in ores taken from the earth, and in very much less quantities in secondary metals, such as drosses, but they must surely be removed before a perfect alloy can be obtained. All act as poisons to lead and cause sluggishness, excessive drossing, and corrosion to the casting mechanism.

Silver is rarely a source of trouble, because of its value, which enables the smelters to profitably remove it.

Iron is rarely encountered as a difficulty, because of the almost negative affinity of lead for this element. It is, however, a factor in the quality of antimony and tin, as these metals absorb iron easily.

Arsenic is a rather common impurity in both lead and antimony, and quite difficult to remove. It whitens the alloys, but in small amounts improves the properties of type alloys.

Zinc is one of the most common impurities, and when present in quantity almost destroys the value of the alloy. The alloy will not absorb a large quantity because the saturation point is less than two per cent. Very small traces are very injurious, even one-tenth of one per cent being objectionable. Fortunately for the producers of metal, zinc is removed rather easily and at low cost. The printer, unfortunately, cannot do this in his plant, as this requires the facilities of a smelter.

The next impurity is copper, and although some type metals contain copper, intentionally introduced, it must be specially alloyed to prevent trouble. A metal high in tin and antimony content, such as hard foundry metal will absorb and hold copper in alloy with success, but the lower metals are almost uniformly injured by its presence in any but small traces.

Copper does have a hardening effect upon the alloy, but not of sufficient amount to make its presence advisable except in the instance cited. The lead smelters usually remove copper by forming a matte, which is easily accomplished on account of the great affinity of copper for sulphur in the ores.

## Typical Analysis of Commercial New Metal Offered by Refiners

| | *Tin per cent* | *Lead per cent* | *Antimony per cent* | *Bismuth per cent* | *Arsenic per cent* | *Copper per cent* | *Iron per cent* | *Silver per cent* | *Zinc per cent* |
|---|---|---|---|---|---|---|---|---|---|
| Tin No. 1 . . . . | 99.938 | trace | .017 | .000 | .019 | .022 | trace | .000 | ----- |
| Tin No. 2 . . . . | 99.928 | .000 | .002 | .042 | .002 | .026 | trace | .000 | ----- |
| Tin No. 3 . . . . | 99.200 | .396 | .300 | .007 | .037 | .100 | .013 | trace | ----- |
| Tin No. 4 . . . . | 95.280 | 3.995 | .381 | .020 | .050 | .106 | .026 | .018 | ----- |
| Lead No. 1 . . . | .0050 | 99.933 | .0045 | .05 | .0015 | .0015 | .002 | .0015 | .0015 |
| Lead No. 2 . . . | .005 | 99.726 | .005 | .25 | .005 | .0025 | .002 | .002 | .002 |
| Lead No. 3 . . . | .005 | 99.931 | .005 | .005 | .005 | .04 | .005 | .002 | .002 |
| Antimony No. 1 . | trace | .102 | 99.608 | .000 | .092 | .046 | .004 | .00 | .034 |
| Antimony No. 2 . | .00 | .029 | 99.760 | .000 | .090 | .012 | .004 | .00 | .027 |
| Antimony No. 3 . | .035 | .018 | 99.915 | .000 | .017 | .008 | .007 | .00 | trace |

## Alloying or Mixing

The purity of a type metal determines its elementary or basic value, yet to obtain satisfactory casting results the component parts — lead, tin and antimony — must be homogeneously bound together in a perfect alloy.

To use an illustration, suppose we should throw salt into cold water and stir. A small quantity would dissolve and the balance remain suspended and on the bottom of the dish. If this water is heated to boiling, however, it will all dissolve, producing a clear brine solution. Just so with lead, tin and antimony. At first there is an incomplete solution of one metal in the other, but upon proper treatment these may be brought into complete solution and a perfect alloy produced. Metals not properly alloyed cause trouble in mixing with a metal supply, but eventually with repeated remeltings these metals amalgamate and form a complete alloy, although this process may take weeks or months in a publisher's plant. This is one of the secrets of manufacturing a successful alloy, and is completely covered by our eutectic process.

The micro-photographic sections of metal, made in our laboratories by our metallurgists, show some very interesting crystal formations. The crystal formation cannot be detected by chemical analysis as it is purely a physical condition and must be studied with the help of the microscope.

Micro-photographs Figures 1, 2 and 3 exhibit a very interesting study in that they all represent samples of type metal of practically one composition or analysis.

They clearly demonstrate the ability of the microscope to detect the essential difference in crystal structure of the alloys.

All pictures were taken at a magnification of fifty diameters and are therefore produced under similar conditions.

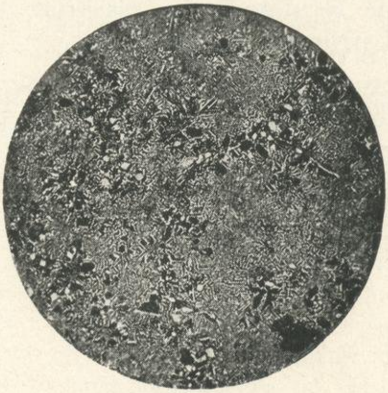

**Figure No. 1**

Figure No. 1 is a section of a sample of new Line-slug Metal correct as to chemical composition, but incompletely alloyed.

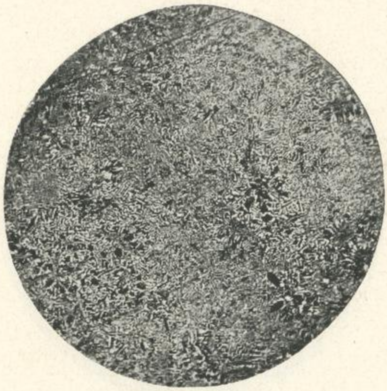

**Figure No 2**

Figure No. 2 is a sample of the same grade of metal when completely alloyed.

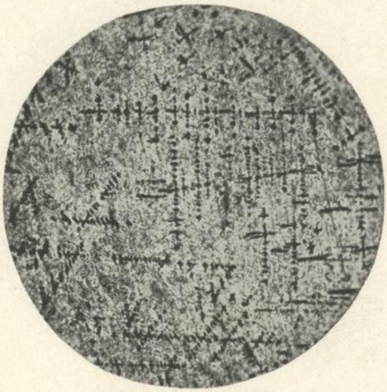

**Figure No. 3**

Figure No. 3 shows a section of metal which was causing trouble in Line Slug machine operation. The metal has the same composition as sample No. 1, but is contaminated by copper and is also in a different state of alloying, causing hardness of the slugs and general casting trouble.

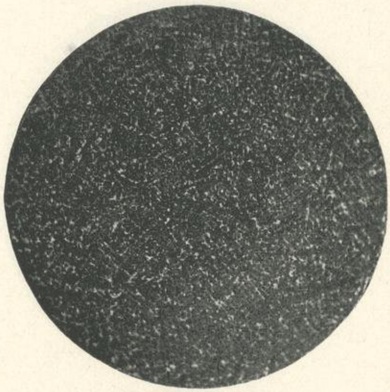

**Figure No. 4**

Figure No. 4 is of a section of Electrotype Metal, showing the uniform structure of the alloy when below the eutectic (alloy of lowest melting).

Line Slug Metal is more nearly a eutectic alloy than any other type metal used.

**Figure No. 5**

Figure No. 5 represents a section of stereotype metal, the sample being taken from a newspaper plant where the metal is constantly undergoing severe daily use. The white spots shown in this photograph are the crystals of antimony-tin alloy imbedded in the eutectic structure. We consider this typical of a good stereotype metal.

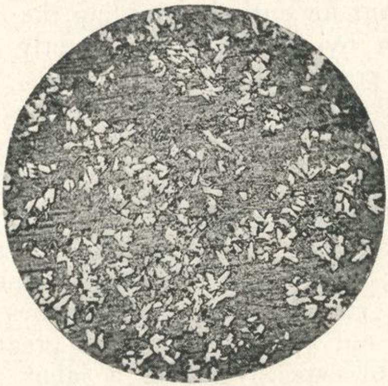

**Figure No. 6**

Figure No. 6 shows a regular Monotype Metal and here will be seen more markedly than in the other specimens the white crystals of antimony-tin alloy. This is to be expected, as this brand of type metal contains a higher percentage of antimony than the stereotype alloy.

## Remelting

Too often the mistake is made of underestimating the importance of remelting type metal. We cannot forgive the occasional small plant for entirely avoiding the remelting operation by feeding slugs directly into the machine pot. The reason is obvious. Nor can we forgive the plant that has outgrown its old remelting furnace and is postponing the purchase of a larger and more efficient type.

In selecting a furnace for remelting the error made is commonly one of undersize capacity, rather than oversize. Remembering that the remelting of small batches of type metal is not only conducive to greater dross waste and expensive from a labor and fuel standpoint, the chief difficulty lies in obtaining uniformity in the mixture of these small doses. Therefore it is far better to feel that the furnace is too big, rather than too little.

It is advisable, in the average plant, to have the remelting furnace situated in a small room by itself, with proper light and ventilation. Equip the furnace with a suitable thermometer, or better still — a thermostat — and have on hand at all times a good supply of flux and Plus metals.

Suitable remelting equipment and an adequate supply pay well in saving of dross formed and proper maintenance of the uniformity of the metal supply so that the expense of these items is more than justified.

*Caution:* Where two kinds of metals require remelting, exercise great care in keeping them separate so as not to unbalance the proportion of ingredients in each of them.

The metal which is in proper condition for the best practice may be very speedily damaged to a considerable extent by improper handling in the re-melting process.

The most expensive element in type metal is tin and unfortunately it is also the element of lowest melting point and therefore oxidizes at the lowest temperature.

It is due to this property of the element which causes it to be reduced in the alloy more rapidly than the other elements and thus becomes the most expensive loss in drossing.

The rate of dross formation is proportional to the temperature, and surface exposed, and the time of exposure. Metal should always be handled at the lowest possible temperature and in the shortest possible time.

As copper and zinc are both soluable in a type alloy, care should be exercised to prevent zinc, brass or copper from finding their way into the re-melting pot.

As dross may be carried in mechanical suspension in the metal, the metal should be carefully skimmed before pouring in order to prevent this oxide from being cast in the pigs.

The black material skimmed from the top of the re-melting pot which is often erroneously called dirt, is as a matter of fact an oxide of type metal of considerable value so that it should be carefully saved and returned to the smelter.

Due to the constant dross loss in re-melting the supply of metal is depleted both in quantity and quality so that a chemical analysis should be made of the metal periodically in order to determine its condition and provide the necessary treatment.

A considerable amount of care should be used in re-melting metal in order to reduce the natural losses to a minimum from the causes mentioned above.

The usual impurities that find their way into a metal supply are copper and zinc, and both of these sources of contamination should be carefully avoided.

## Drossing of Type Metal

When metal is heated to the point at which it melts and above, and the surface is actively exposed to the oxygen of the air it tarnishes or oxidizes just as iron rusts. This oxide is commonly called dross.

There are several points to be considered in regard to the drossing of metal. Its rapidity or velocity of oxidization is dependent on several distinct factors. (1) Temperature. (2) Time. (3) Agitation. (4) Purity.

(1) Temperature: — The higher the temperature of the metal the more readily it absorbs oxygen from the air and the greater

the amount of dross formed in any given time. (Therefore let the metal freeze, if possible, when not in use, at any rate keep as cold as practical.)

(2) Time: — The amount of dross is dependent on time of exposure to air. In two hours just twice as much oxidization takes place as in one hour, other things being equal.

(3) Agitation: — The amount of dross is very much increased by continually exposing fresh surfaces to the air, therefore agitation greatly increases amount of dross formed. (Don't agitate more than is absolutely necessary).

(4) Impurities: — These work out of the supply and into the dross with repeated remeltings, but the amount of dross is excessive. In this, metal closely parallels the flowing stream which purifies itself on its course by exposure to the air.

This is most fortunate, but on the other hand it is one of the reasons why it pays to buy a pure metal. An impure and therefore cheap type metal not only gives unsatisfactory results in use, but the *excessive dross much more than offsets any savings in its initial cost.*

## Deterioration of Type Metal

Now let us consider the question of what has happened to the composition, or analysis, of type metal as dross is formed.

We have heard some amusing comparisons of metal to old shoes, old suits of clothes, and nearly everything conceivable to illustrate the difference between the old supply and the incoming metal. Let us state right here that metal long in use *does not wear out*. It will become low in certain elements, it will absorb impurities, but if the metal is given proper treatment to remove impurities and lost tin or lead restored, the metal can again be made similar to the original metal. It never wears out like a pair of shoes, or a suit of clothes. It is more similar to water, it may have impurities such as salt, it may get dirty with mud, but evaporate the water and condense the steam and we have pure water once again. There is no way of doing this with a pair of shoes.

The question is often asked as to whether the supply has lost more lead, tin or antimony in this process of repeated remelting and use. We find by tests that the natural thing has happened. The element of lowest melting point drosses faster than the others, and this is the tin in the alloy.

The next in point of melting is lead and we find more loss in this element than the last or highest melting point, antimony. The alloy which contained originally 5% tin, 12½% antimony and 82½% lead is after repeated use probably 4% tin, 13¾% antimony, 82¼% lead. The antimony by slower oxidization rises in percentage as the lead and tin dross more rapidly.

## Sources of Contamination

A type metal supply must be most carefully guarded constantly against contamination with foreign elements, which are harmful to the proper operation of the metal for the purpose for which it is intended.

Care should be taken not to mix metal intended for different kinds of work. Thus electrotype metal should never be mixed with a stereotype supply, as the low antimony content of the electrotype metal will seriously reduce the amount of antimony of the resultant mixture below the proper amount for which the supply is intended and thereby render the supply useless.

By the same token line-slug metal should be kept separate from the harder monotype metal.

As previously explained, zinc and copper are both harmful elements for the best casting results. As these are the most usual impurities with which a type metal is contaminated in a printer's plant, we need only consider them.

Zinc can easily be introduced by brass rules, matrices, zinc etchings or zinc sawings finding their way into the melting pot. When metal is heated in the presence of zinc, it will absorb the zinc, even at temperatures considerably below the melting point of zinc. In "killing matter" the zinc etchings, as well as brass rule should always be carefully separated from the type matter before melting.

Brass matrices, as well as brass sawings and bits of brass rule, are apt to become mixed with type metal recovered from the floor sweepings, so that this class of material should be very carefully inspected to eliminate this source of contamination. Copper half-tones and electrotype plates should never be allowed to enter the melting pot.

Too much care cannot be exercised to prevent the introduction of these impurities into the supply, as the troubles encountered by reason of this contamination are exceedingly annoying and very difficult to eliminate.

After using every precaution to prevent the introduction of any zinc or copper bearing material into the melting pot, the heat should be applied slowly, so that the whole mass may become evenly heated without certain portions becoming over-heated.

As soon as the whole pot of metal has become molten the foreign matter rising to the top should be carefully skimmed off, if the metal used is of low tin and antimony content, such as line slug metal. If the metal is of composition used for stereotype practice, the skimming should be performed at about 650° F., or higher, depending upon the antimony content of the metal. The metal used for casting unit type, should be skimmed at 750° F. If the skimming is done at lower temperature, a considerable amount of antimony and tin, which are above the saturation point may be removed in the skimming.

To release the free metal from the dross, a flux should be sprinkled over the surface of the pot.

Lard oil may be applied to the surface of the pot, as its combustion produces heat in the layer of dross. This temperature increase will liberate metal from the dross and leave a fine powdered dross. This dross can then be easily skimmed off and, when cold, deposited in steel dross drum ready for shipment to the smelter.

The reason that dross should not be skimmed directly into the drum is that if it contains free metal this value is lost to the printer. The dross should be skimmed into a shallow pan or plate, on the floor. The free metal will then run out of the dross and can be returned to the supply. The dross being placed in the drum after this separation.

The metal supply should be cleaned at intervals with organic material introduced at the bottom of the molten metal in a bomb or gun, simply designed for this purpose.

The metal in a daily newspaper plant should be thus cleansed once a month, or oftener, if contamination occurs. Line slug metal should be so cleaned after every fifteen or twenty remeltings.

The skimming should be continued, until the surface of the metal is clear and bright with a mirror-like surface. Long, fine cob-web lines will then form over the surface indicating that the skimming has been properly performed and the metal is not seriously contaminated with zinc.

## Dross Reducing Furnaces

The reclaiming of usable metal from dross consists of three distinct operations, namely, the reduction of the oxide to the metallic, the purification of the metal, thus obtained by reduction, and the adjusting in proper proportion the constituent parts of lead, tin and antimony. The last two processes require the greatest amount of time and skill, as well as incur the greatest expense.

As all ores and drosses are impure, it is manifestly impossible to produce by the deoxidization of these alone, a metal which will operate satisfactorily without scientific chemical treatment to insure purity. This must be done by the experienced smelter with special equipment designed for the elimination of harmful impurities. Various furnace devices have appeared, on the market, for the recovery of metal from the dross by the publisher, but as yet they all fall short of the desired mark, as they entirely overlook the absolute necessity of purification and standardization. If the dross reduced to the metallic state is used without purification the very impurities, which are harmful and which have been so carefully guarded against, are re-introduced into the metal supply and in due time are the cause of trouble. The cost alone of reducing dross in small quantities makes the use of these devices prohibitive and almost non-existant.

After purification of any metal by the smelter it is necessary to analyze chemically to determine the percentage of each element which is present and carefully add the necessary ingredients to bring the alloy to the proper standard composition for use.

## Line Slug Metal

There are several features concerning the metal for use in Line Slug casting machines, which are different from other metals, used for type purposes.

These machines are operated with a casting temperature of 520°-550° F., which is considerably lower than is used with any other kind of type metal. At this low temperature range, metal will not flow satisfactorily, unless it is entirely alloyed and perfectly uniform throughout, as well as free from impurities.

The metals of higher composition than Line Slug Metal, and also of lower composition, would not be sufficiently free flowing and would freeze in the port-holes of the casting mechanism so that they could not be worked at the low temperature.

In addition to the metal being in proper condition, the adjustments of the machine must also be properly made, or the results cannot be satisfactory. This is especially important in newspaper plants having a stereotype foundry with dry mats in use. As the pressure required to mould a dry mat is greater than that for the wet kind — being as much as 500 tons — it is obvious that only slugs and type without cavities will withstand this pressure without breaking down. As the Line Slug casting machine is an intricate mechanism, it is often exceedingly difficult to determine whether troubles when they are present are due to the machine, or faulty metal.

A "squirt" is one of the most common troubles and may be due either to the metal or machine adjustment. If due to metal trouble, it is usually caused by an excess of tin, while if a machine trouble, it may be caused by several faults, notably — imperfect lock-up.

"Stuck slugs" may be produced by any one of at least fourteen different factors, none of which concern the actual quality of the metal. The temperature of the metal being too high, or too low, may cause a slug to jam or stick, but the usual cause is mechanical.

"Porous slugs" are generally caused by any of the following: (a) dirty plunger, (b) metal temperature too high, plugged mouth-piece port holes, (c) shallow mouth-piece vents (the sprues should be ½ to ¾-inch long), and stopped pot well holes — all of which should be cleaned daily. This condition may also be produced by insufficient tension on the plunger lever spring or by a worn plunger or well or a tight plunger.

"Poor faces" are usually caused by the above-mentioned conditions. If the face, however, appears cold or frosty, the temperature should be raised somewhat before the next cast is made.

A collection of hard dross in the throat of the metal pot, which interferes with the free flow of the metal is another cause which has been known to occur in pots heated imperfectly. There is only one remedy for a case of this kind, which is to remove the obstruction with a dross saw or replace the pot with a new one.

It is important that the port holes of the mouth-piece should line up perfectly with the edge of the mould, in order to allow a free flow of metal into the mould. The port holes can be properly aligned by means of the pot leg adjusting screws.

As Line Slug Metal is operated at low temperature and must flow through very small port-holes the introduction of copper into the supply must be very carefully avoided, or various troubles will be encountered.

When copper is present, it will cause cutting and clogging of the mouth-pieces, as well as hardness and brittleness in the slugs cast. As the copper is contained in the metal in minute crystals, which are exceedingly hard, it produces dulling of the knives on the machine in addition to the troubles above mentioned.

As tin is lost more rapidly than any other element by overheating, and as the proper amount of tin is very necessary to produce the desired fluidity for line casting operation, it is especially important to guard against overheating of line slug metal and thus preserve the metal in balance for proper working.

It is impossible to urge too strongly the use of a thermometer with Line Slug Metal, in order to guard against the over-heating in the remelting pot and insure the serviceability of your metal.

## Stereotype Metal

Stereotype metal for newspaper use is the most sensitive of all the metals and is the real test of a manufacturer's product as to purity and perfectness of alloy.

It is the most rigorous because the plates cast, including tail, usually weigh over sixty pounds and when such a large volume of metal is used, the troubles are very much multiplied by the slowness and unevenness of cooling.

An inferior metal may show itself in many different ways. One may encounter sinks, hot streaks, cold half tones, porous plates and even disintegrated type at tail end of plate, if conditions are sufficiently bad. These conditions may be brought about by different causes and their elimination therefore made much more difficult by being unable to immediately discover the cause of the trouble.

These troubles, from an inferior supply, however, may all be classified under the three heads of, (1) Impurities, (2) Supply out of balance as to lead, tin and antimony, (3) Incomplete mixture of the elements.

Not only is stereotype metal the most sensitive, but in addition receives in most cases the hardest use and therefore undergoes the greatest deterioration of any of the metals. In most plants the stereotype supply is at 600° F. or above for six hours out of every twenty-four. None of the other metals undergo a service of this severity. *Of course the result of such use is an abnormal deterioration* and therefore the need of careful watching by means of periodical analyses by the metal house.

If the metal is used without undue overheating, and in a normal manner, the incoming shipments of adjusting metal *known as stereo-plus metal*, in weight always equal to the quantity of dross shipped, will take care of this depreciation in the costly constituents. It is also necessary that only metal of good quality be added.

Just as soon as the metal depreciates below a certain standard the results become less satisfactory and hot streaks and many other annoying imperfections are noticed. We have known of cases where in a few days a supply has crossed this critical point and the supply changed its character completely, so that although giving good results the previous week, the present results were distressing. Of course every stereotyper knows that a low casting temperature is always desirable, but we have frequently found cases where the casting temperature could be lowered as much as 75° and a better result obtained by simply reducing the water supply.

We therefore, would recommend that all workers should make a few experiments to be sure that they are really working at lowest practical temperature with a minimum of water in the casting boxes.

This lower temperature not only saves the loss of valuable tin, but greatly reduces the quantity of dross produced and fuel consumed.

As the tin works out of the supply, the

operator finds that the required casting temperature rises and as this goes up the amount of dross increases so it is really a saving in money to restore the tin and thereby reduce the casting temperature to save metal waste.

The correct casting temperature varies for different equipments, and therefore must be determined. For newspaper plants a temperature of 650° F. is about the high limit and when a temperature above this is required, an investigation is advisable as to the composition of the alloy, etc.

The pyrometers in general are apt to need adjustment at intervals, so we recommend that each stereotyper equip himself with a thermometer such as sold by the various composition machine manufacturers at a low price, and that this be kept handy, so that the pyrometer may be checked and corrected from time to time.

The discussion above has not covered the impurities most likely to be encountered in stereotype work, so we will mention briefly that much of the trouble in stereotype supplies is caused by permitting foreign metals such as zinc, copper, electrotype and foundry-type to contaminate the supply.

Zinc is the worst and most likely source of trouble. It is extremely poisonous to the supply and is apt to enter, unless carefully guarded against, because of the close proximity of the engraving room in most plants.

Now that nickeling of stereotype plates is coming into common practice for color and magazine work, there is an additional source of trouble likely if the plates have had a preliminary layer of copper before nickeling. In remelting these nickel-types therefore, great care must be taken to work at a low temperature to avoid copper contamination. Nickel being practically insoluble in type metal at ordinary temperatures is not considered a source of danger.

Electrotype is a soft metal, low in tin and antimony, so naturally must be kept from the supply.

Foundry-type is always copper hardened, and although carrying high tin and antimony, must be avoided also because of the copper.

In operating a stereotype pot it is advisable to permit the dross to accumulate to a depth of one inch, rather than to keep the pot free from dross. The reason for this is that the blanket of dross retards oxidization of the supply by protecting it from the air.

We wish to again emphasize the need of periodical analyses of the stereotype supply because of the unusual severity of all newspaper work. Our laboratories with their trained chemists are at your service for this purpose and there is no charge for the reports.

As stereotype metal carries a percentage of antimony above the eutectic it is important that it should not be skimmed at low temperatures.

If the dross is removed at a low temperature it will carry with it free metal which will remove an abnormal amount of antimony and tin. This is due to the reduced fluidity at low temperatures and the tendency to segregation of the antimony and tin.

When this improper skimming takes place the metal supply is lowered in antimony and the casting results are seriously affected.

A stereotype supply in proper condition should operate satisfactorily with either wet or dry mats.

## Combination Metal

Where the same metal is used for both stereotyping and line slug casting, it is customary to use a metal slightly higher in antimony than is the best practice for line slug casting. This should not be overdone, as the operation of the line slug machines will not be as satisfactory as it should be.

As the name, combination, implies, it is a special metal designed for use in both the Stereotype Foundry and the Composing Room, and is therefore of a composition which will give reasonably good service for either type of work. It is not of the ideal formula used for either of the other metals, but rather a compromise. Where this system of operation is used, we would recommend that care should be exercised to see that all metal in the plant is handled in such a way that the entire supply may become uniformly mixed and that the metal in both departments is thus in the best possible uniform condition for use.

## Monotype Metal

The monotype machine is more flexible with regard to metal than other machines, and for this reason we find four distinct grades of metal in use and all giving satisfactory results from a type casting standpoint.

(1) The softest metal being used today in the monotype machine is regular line slug metal. This metal has come into common use in newspaper plants where non-distribution has been installed. The advantages are many, but the most important is that one supply of metal can be used throughout the composing room. The line slug mixture always sells for less than monotype metal, so a considerable saving is effected with no loss of efficiency.

This mixture is a softer metal and therefore we find less wear and deterioration in the casting parts; so here again is a saving. There is less heat required to operate with this metal, and we often find successful results being obtained from 625° F. to 720° F., except on the very small sizes.

Occasionally we have found printers, doing book and job work, operating with this grade of metal, and undoubtedly there are cases where perfectly successful results are obtained and a saving realized because of the nature of the work, *but it is not to be recommended for average work.*

(2) The next grade of metal is commonly known as regular monotype metal, and is suitable for most grades of printing. The antimony and tin percentages have been considerably increased in this metal over the line slug formula, but are lower than the monotype

formula recommended by the Lanston Monotype Machine Co., of 9 per cent tin, 19 per cent antimony, and 72 per cent lead.

It has been adopted by the metal houses because of its satisfactory results and cheapness. It not only saves the printer money in his metal cost (usually being one cent per pound or more cheaper) but produces less wear on the casting parts.

Of course, it is not suitable to all requirements with respect to hardness, but should always stand up for a much longer run than line slug metal.

(3) The formula recommended by the Monotype Co. of 9 per cent tin, 19 per cent antimony, 72 per cent lead, is sold by the metal manufacturers under the name of "official monotype." Largely because it is for particularly fine work and is the unusual rather than the usual metal bought by the printer, however the demand for this grade is steadily increasing.

It gives very satisfactory results. It is harder than the other mixtures, takes more heat to run and shows greater wear on the casting parts. It should always be recommended where hardness and perfection of face are required. Its higher price is offset by these advantages.

(4) The fourth grade of metal sold for monotype machines is "job type" metal whose hardness approximates that of foundry type. This metal is sold under several names by different manufacturers.

It is never intended for composition work, as it can not be cast at composition speed. It is designed for casting display type and sorts to replace foundry type. It should be as hard as metal used by the foundries and give a product equally satisfactory if cast with care.

The usual reasons for defective type in the operation of the Monotype are: (a) worn bearings in the pump mechanism, (b) worn piston or pump body, and (c) improper temperature. Too much stress cannot be laid on the necessity of the operator examining and cleaning the pump body and nozzle each shift. Unless this is done even new metal will not cast satisfactorily for any length of time.

## Electrotype Metal

The commercial electrotype alloy will vary in percentages of tin and antimony with the different manufacturers, but as a result of many analyses the tin has been found to vary between 1¾% and 5% and the antimony between 2% and 3½%. A great quantity of the electrotype metal today, is made 2½% antimony and 3% tin with the balance, 94½% lead, but much is most unsatisfactory because of the large variation in formula between different lots from the same manufacturer.

The reason for this is that competition has forced the manufacturer to make up the metal from old materials. Just figure the cost of an alloy containing 3% tin and 2½% antimony, balance lead, using new metal market values and compare with your quotations for the alloy. You will thus prove for yourself that old materials are being used.

As a matter of fact there is no scientific reason why satisfactory metal cannot be obtained from such material as old electrotype plates, if properly purified and brought to correct and uniform analysis. It is the failure to obtain these conditions however, that causes inferior metal and brings the many troubles into the foundry that sometimes are never traced to the metal, but suddenly disappear as the next lot of metal is put into use.

When a miscellaneous lot of old plates and other materials are melted down, an alloy of varying and undetermined composition and purity results. It is entirely unsuited for electrotype use in this condition and is only suited for the experienced chemist to analyze, purify, and bring to standard analysis.

About four out of every five companies are controlling these operations by the workman's eye and believe they can produce a metal that will be sufficiently satisfactory under this system. It is true that many times the metal will prove acceptable under these conditions, but they slip seriously, now and again, with respect to the purity and universally with respect to uniformity of analysis. There never has been an experienced smelter who could with any certainty, tell the analysis of an electrotype metal by an "eye inspection."

When the smelter slips, the metal goes to the electrotyper, causing many expensive failures and delays, upsetting the entire routine of the work, thereby destroying the efficiency and low cost of output. Not only this but many of their customers in turn suffer loss and inconvenience. If the manufacturer was forced to stand the expenses of these mistakes he could not afford to operate without an experienced chemist and a laboratory. The remarkable part of this practice is, that the electrotypers by buying cheap metal can save approximately ¼c per pound compared to better grades and risks so much, that it is taking a ten to one chance on the wrong side.

To go more deeply into the troubles that are brought about in such cases, we will discuss, first, the lack of uniformity of analysis.

The man who pours the metal in the foundry, or does the backing, is accustomed to work with metal at 650° F. except in unusual cases. Most foundries have pyrometers to permit them to maintain this uniform temperature at all times. All finishers become accustomed to metal of a certain hardness, and their skill in using the hammer and chisel is very much dependent on maintaining a certain hardness of metal. Their touch must change if the hardness of the metal is changed.

If an alteration is made in the percentage of antimony of as little as one-half of one per cent, both the backer-up and the finisher are thrown out of their stride and will notice the change in hardness of metal. If the metal is below 2½ per cent antimony the plates will lack stiffness and fail to retain their shape when curved. They will be too soft to stand heavy pressure on press, and will often take marks from rolls on half-tones while finishing. This metal is also stringy and clogs saws and cutters like lead. When the antimony is above 3½ per cent and tin is not over 3 per cent, the metal is too brittle to bend safely without cracking, unless the bends are made the same day that metal is poured. It is a well known fact that the metal of the plate hardens very much upon standing a day or more.

It is thus seen that the composition of the metal must be made within rather narrow limits and that variations when not dangerous are very inconvenient in the foundry and finishing departments.

The tin may range between 2½ and 3½ per cent with less change in properties of the metal than is the case with the antimony, but when less than 2¼ per cent serious results, such as peeling of shell, are apt to take place.

It is also seen from the above illustrations of the narrow limits for good results and the sensitiveness and seriousness of small variations in antimony and tin, that it is impractical to attempt to control the manufacture by rule of thumb.

The question of impurities is even more important and should be considered carefully. The most usual impurities are copper and zinc, as both are present in the electrotype foundry, and in old plates at all times.

Copper shells are always tinned with what is commonly called tin foil before backing metal is applied. This tin foil is really solder foil, having less than 50 per cent tin and balance lead. The effect of this material is to alloy the entire back of the shell uniformly with the solder. This produces a surface which will in turn receive and form a uniform bond with the electrotype metal. The electrotype metal alone would not do this, because of its low percentage of tin. Thus we have the backing metal indirectly alloyed with the copper, and when these plates are remelted and shells skimmed from the surface of the pot, the metal is contaminated with copper from the soldered or tinned face.

In shops where metal is used over and over, there is excessive contamination from copper and the metal becomes quite sluggish and hard. In addition there is noticed excessive drossing. When plates are "re-run" by the electrotyper, contamination may be greatly reduced by performing this operation at low temperatures, preferably about 610° F. and using salamoniac to free the greater part of the metal from the shells previous to skimming.

If metal has been contaminated with copper, a partial purification may be accomplished by permitting metal to freeze and then remelting without stirring. After this the surface of the metal is skimmed until it becomes clear and there are no small particles seen just under the surface. If this is done carefully the really detrimental amount of copper will be entirely removed. In explanation it may be stated that copper alloys, with the tin and antimony of the electrotype metal to form needle-like crystals, which are lighter than the balance of the alloy. As freezing and melting take place these float to the surface and can then be lifted out of the mixture.

The second most common impurity is zinc, and this is more dangerous than copper. The melting point of zinc is very little higher than lead, and therefore, when zinc cut electrotypes, or zinc of any kind finds its way into the pot, it melts and contaminates the alloy.

Zinc in quite small percentages affects greatly the fluidity of the metal. Not this alone, but the fact that it continually floats to the surface, because of its lighter gravity and incomplete bond with the other metals, causes a film, or cold shot, to form when it is poured over the tinned shell and prevents a perfect adherence between the metal and shell. This causes spots under the shell so that blisters will appear in the plate after running on press a short time.

Zinc does not affect just an occasional plate, but is found in spots in every plate, although in type matter the plate may be used and the imperfection not detected. This is not the case with half-tones. These plates must all be re-made or the defect may not appear until running on the press with the well-known unpleasantness for the electrotyper.

It is a difficult matter to remove zinc from metal in an electrotype foundry, as the purification from this metal is performed at red heat, using such fluxes as salamoniac, sulphur, and rosin. It is, however, a rare case to find that this impurity has been introduced by carelessness in the electrotype foundry. It is a very common occurrence for smelters to encounter this difficulty when melting old materials, and it is for this reason that they must be most conscientious in guarding against it before pouring any batch of metal.

Iron is very rarely encountered in a metal as low in tin and antimony as electrotype metal, and need not be considered.

Arsenic is an impurity that is very injurious when present, as it destroys the bond between the shell and the backing metal and causes sluggishness. This same effect is sometimes produced by pouring metal at very high temperatures. In such cases the tin foil is absorbed from the copper shell before the metal sets, and there is then only the bond between the shell and the electrotype alloy, which is very insecure and apt to peel while bending or finishing.

It is a rare thing to encounter arsenic in the electrotype metal in dangerous percentages.

The loss to the electrotyper occasioned by impure metal is not confined to the great loss in defective work alone, but is also in evidence if careful records of percentage of dross per pound of metal are kept and studied. It is safe to say that the variation here alone will more than offset the saving in using an inferior metal, if the saving, as is usually the case, is not over one-quarter of a cent per pound.

Variations in composition, even though the metal be pure, must not be overlooked just because the more serious and costly difficulties arise from impurities.

## Sampling

The proper sampling of a metal supply is very important where it is desired to have a chemical analysis made which in any way represents the metal sampled.

In order to obtain a representative sample of a metal it is not correct to take one piece from one plate or slug, or one piece of a pig, as for instance the ear, as representative of the whole supply.

To sample a line slug metal supply, one small ingot should be poured from remelting pot after thoroughly stirring the metal in pot or a small quantity of shavings may be collected from under each machine operating and this when thoroughly mixed will be a representative sample.

To sample a stereotype supply, stir the pot of metal well and then pour small sample ingot. A sample of sawings and shavings taken from trimming machine is also representative.

A monotype supply should be sampled by pouring a small ingot from melting pot after thoroughly mixing.

When only a chemical analysis is desired, a sample of eight or ten ounces is ample, while a pound or two should be provided if a complete physical and microscopic study of the metal is to be undertaken.

The great difficulty in procuring a fair and average sample of the metal has frequently been the cause of much discussion and complaint among metal users who have had analysis made by two or more chemists for comparison. If two or more analyses are to be compared the samples should be obtained at the same time and under identical conditions.

As all alloys separate more or less on cooling, it is unreliable to secure a sample from the ear of a pig or corner of plate. This tendency of the alloy to segregate on cooling is the greatest cause of difficulty in sampling and the reason for recommending the above methods as satisfactory.

## Analysis

The accurate analytical determination of the contents of a type metal alloy is rather an intricate chemical analysis and therefore this work should always be entrusted only to a laboratory having considerable experience in this particular class of determination.

There seems to be a very common wrong impression among metal users that metal will wear out, even without the loss of its elements, or a change of chemical composition. This impression is quite contrary to fact, for the elements lead, tin, and antimony are always the same, and as they are elemental substances cannot change, or deteriorate as long as existing. It is quite true as described, that the alloy may become impoverished by the loss of part, or all of one or more of its component parts. The alloy may become impaired, or seriously damaged by contamination, but as long as the elements are present in proper proportions and correctly alloyed, the resulting alloy must function properly and according to certain very fixed and definite laws.

Many metal users have the impression that two metals or alloys will not mix with each other. The conception seems to be that they will behave very much as oil and water behave. This idea is wholly wrong, and has doubtless been gained from attempting to mix a pure, clean alloy with a badly contaminated one. It is quite true that under these conditions they may not mix readily, as they have very different properties, due to the impurities in the one.

It is impossible to prescribe any fixed and general rule for a toning or temper metal, which will be at all applicable to more than one set of conditions, as it is impossible to predetermine the amount of deterioration of each element. We, therefore, cannot recommend the use of any regular toning or temper metal. Each case must be treated as a special problem and a special alloy should be prepared for every case so proportioned and alloyed as to fit the case under treatment. If a metal supply becomes contaminated with impurities as well as depleted in vital elements it is often more satisfactory and very little more expense to exchange the entire metal supply for new metal than to attempt toning.

In order that metal shall operate perfectly and produce ideal results the alloy must comply with three requisites, first, proper composition, second, proper purity, third, proper microstructure. If any of these three conditions are lacking trouble will be encountered and the problem must be carefully studied and proper remedy applied.

If at any time your metal does not operate entirely to your satisfaction, we will be very glad to study your problem and tell you what to do to restore your supply to its proper condition.

Like most doctors, we will appreciate as much history of the case, and as many symptoms as you can give us so that the case can be carefully analyzed and a correct diagnosis obtained.

## How to Keep Type Metal Fit

As every pound of dross taken from a metal supply represents not only a pound of metal taken from the supply, but also a loss in certain vital elements, it becomes most important to replace each pound of dross with an equal weight of new special metal if the service metal is to be maintained at a uniform amount and standard analysis.

Plus Metal is designed to carry an excess of the elements which are removed from the supply in skimming the dross.

From an exhaustive study of a large number of plants, the average rate of deterioration through drossing has been determined and the Plus Metals have been designed to replace this normal wear when returned to the metal supply in weight equal to the dross formed.

Plus Metals are supplied under the name of the kind of metal for which they are intended, such as Lino-Plus, Inter-Plus, Mono-Plus, Ludlow-Plus, Stereo-Plus, etc., the general practice being at all times to receive a weight of Plus Metal equal to the weight of dross shipped.

This Plus Metal should only be added to the metal supply at such times as the dross is removed and then in weight equal to the dross. If the Plus Metal is added, as above, at each dross removal, both the quantity and the quality of the supply will normally be maintained.

This method of dross replacement is now the general practice in all plants who are careful of their metal and has proven to be a most economical as well as a simple method of maintaining type metal efficiency. If Plus Metals are constantly and correctly used they eliminate the necessity of buying expensive toning or temper metal and insure uniform casting and printed results.

Therefore this plan appeals to the prudent buyer for its economy and also to the production department for its efficiency and uniformity of production results.

## "Don't Blame the Metal"

There are many difficulties encountered with type-casting machines which are at all times too apt to be blamed on the condition of metal when the real trouble is in the machine adjustment and not in the metal.

Of course it is essential to have metal in proper condition in order to obtain a perfect product and this should be carefully checked up by frequent analyses of your metal at the hands of a trained chemist who cannot only analyze the metal, but also interpret the results from a machine-casting point of view.

When squirts, hollow slugs, or bad face are encountered the operator is usually all too ready to immediately blame these conditions on the metal without proper machine adjustments and investigation to insure against machine trouble.

Before blaming your troubles on the condition of the metal be sure that your lock-up is perfect with adequate ventage so that the air in the mould can be released in order to make room for the metal.

Be sure that your plunger fits properly into the well so that it pumps the metal into the mould instead of allowing the metal to leak past the plunger when it makes the stroke.

Carefully investigate the temperature of the metal so that it shall be neither too hot nor too cold as proper results cannot be obtained except under proper temperature conditions.

Be sure that mouth piece and throat of machine are both clean so as to permit a proper flow of metal into the mould.

It is good practice at all times when encountering casting trouble to make every effort to check up the machine adjustments and at the same time to send a sample of your metal for analysis and advice of a capable metal concern who will tell you very quickly concerning the condition of your metal.

It has been found that 90% of the troubles attributed to metal are not metal troubles at all, but can be overcome by proper machine adjustment.

When, however, the trouble is really in the metal, it is always best to replace your metal supply by exchanging it for new metal, or adding special alloy of proper composition for your especial conditions.

## "Never Attempt Toning Without Proper Chemical Supervision"

In order to avoid very serious difficulties it is never safe to attempt toning a metal supply without a careful chemical analysis and satisfactory interpretation of this by a properly trained technical person who understands fully the intricate questions involved.

To illustrate the pitfalls which may be encountered, we will consider a few of the difficulties commonly met with in considering such treatment.

Tin is the element which produces fluidity and yet fluidity may also be obtained by increase of temperature. Therefore if the metal is apparently too fluid, it is necessary to know the proper amount of tin required for the work to be done.

Antimony is the element which is used in type metal to produce the desired hardness, but a degree of hardness and brittleness is produced by copper contamination, which is quite undesirable, as it materially reduces fluidity and causes machine trouble.

Lead, which forms the body of a type alloy, is soft and where metal appears to be too soft it is sometimes assumed that the percentage of lead is too great, whereas tin is also a soft element and the tin content may be too high, or the antimony content too low.

Don't be misled by the feeling that the metal analysis can be determined accurately by means of an inspection of the fracture, as the crystalline size and structure is determined very largely by the temperature of pouring and the rate of cooling, so that these conditions must all be carefully considered if any sort of information is to be gained from the fracture.

The condition of a metal supply is of utmost importance for the best results and the value of the supply is too great to gamble with. Therefore it cannot be too strongly urged that analyses should be made of the metal condition. This work must be handled in properly equipped laboratories and the results of these analyses should be carefully interpreted by those who are familiar with type-casting conditions and therefore able to prescribe the proper treatment.

In order that you may have a complete record of your metal, always maintain a file of the results of these analyses. When these results are compiled over a considerable length of time the record will form a very valuable means of checking and predicting the possible sources of trouble before the trouble occurs.

## A Few Helpful Hints

The reputable metal manufacturer is always willing to help his customers to get the most efficient operation from metal supplied by him. A reliable concern stands back of its metal both as to quality and service. If a manufacturer does not render aid of this character then it is time to seek a new metal source when buying.

It's always a wise idea to send samples of metal to the manufacturer, at regular intervals, to be analyzed. This enables the printer, as well as the firm responsible for the manufacture of the metal, to keep informed as to the exact condition of the supply. Most firms do not charge for this service and the use of the service frequently discloses trouble symptoms in time for treatment before they become serious.

Steel containers or drums are also loaned without charge to the printing plant for the careful storing of dross. After these are filled and turned in for Plus Metal, they are returned to the printer for future accumulations of dross. This is a much better method than the old wasteful custom of trying to ship dross in old ink barrels and other miscellaneous containers which happen to be lying around.

If the following simple rules are observed in the care of type metal we can conceive of no supply ever being the cause of unsatisfactory results.

# EVERYDAY PROBLEMS
## OF THE
# TYPE METAL USER
## AND
# THEIR SOLUTIONS

THESE questions and answers are offered only as an aid to overcome the more common difficulties that occur in the average plant.

The questions on the following pages have been answered by our mechanical friends in the printing industry and we wish to thank them for the time and thought they so willingly gave to help make this possible.

We are not experts in these mechanical problems but wish simply to pass these few pages along with the hope that they will be of value and interest.

## Contents

## Slug Machines

Q. 1. When is the Linotype Metal meeting best the requirements of the Composing Room?

A. When slugs produced are solid in body and possess sharp, smooth faces. The Linotype Metal must, therefore, be of proper formula (3.5%-4.0% Tin and 11.5%-12.0% Antimony), free from impurities, and the machine temperatures adjusted to permit casting between 520° and 550° F., depending upon type size.

Q. 2. What causes throat of a slug machine to clog?

A. Contaminated metal, unbalanced metal, or metal improperly alloyed. A faulty casting with an obstruction in the throat of the crucible. Metal carelessly remelted and skimmed. Low temperatures. Metal level below top of well.

Q. 3. How often should the plunger, vents and jets be inspected and cleaned?

A. Inspect all daily. Clean plunger once each shift. Drill jets and reopen vents once every day.

Q. 4. Name some causes of a backsquirt.

A. Poor lock-up; warped mold; excessive tin; vents too deep; bent liners; pot leg adjusting screw loose; metal on face of mouthpiece; dirty plunger and well; broken pot lever spring; vise locking stud loose; pot lever out of adjustment; over-heated metal; metal level too high; warped mouthpiece. Also Q. 8 causes squirts.

Q. 5. What causes hollow slugs?

A. Loose or tight fitting plunger—hot or cold metal—metal low in pot—dirty metal, causing sluggish flow—weak tension on plunger lever spring—portholes and bottom of pot well clogged—hot mold disc—clogged jets in mouthpiece—clogged vents in mouthpiece—vents too shallow (sprue from vents measure ¾″ long)—improper pot alignment—throat of pot clogged—deteriorated metal—roughness inside the pot, just back of mouthpiece, interfering with free flow of metal through jets.

Q. 6. (a) What causes metal to ball up on the plunger of a slug machine?
(b) How would you overcome it?

A. (a) The metal ball-up on the plunger is caused by the metal in the pot being colder at the top than it is at the bottom. This is generally caused in a machine near an open window, or where the operating speed is quite rapid and they put in cold metal about as fast as, or a little faster, than it is being cast. (b) The way to overcome this in the first case is to protect the crucible from the draft; and in the second case, to wrap the plunger rod at the metal line with a piece of thin brass or aluminum. The metal will not adhere to these metals and will at all times keep the plunger rod clean.

Q. 7. How much metal should be in the crucible and why?

A. One-half inch below (not over three-quarter inch below) crucible ring; if higher, the metal will rock out through the mouthpiece, and if lower, the elements, in case of an electric pot, become exposed and dross is sucked down with the plunger with subsequent fouling of throat or mouthpiece.

Q. 8. When the jet marks on the slug run over the edge, or show only fractionally, what does this usually indicate?

A. The crucible is out of alignment. This can be adjusted with the pot leg screws.

Q. 9. Name several causes for slugs chilling.

A. Lack of heat under the pot, throat, or mouthpiece; an under-size plunger; too much water; air used to cool mold disc (where water is used on mold disc); dirty mouthpiece or jets; poor lock-up; improper pot alignment; unfit metal; lack of ventage; and not enough tension on the plunger spring.

Q. 10. What causes "stuck slugs"? Give a remedy.

A. Stuck slugs are caused by: 1. Dirty molds. 2. Warped mold cap. 3. Bad liners. 4. Hot metal. 5. Weak clutch spring. 6. Oily clutch leathers. 7. Dull trimming knives. 8. Jammed ejector blade. 9. Metal level low in pot. 10. Knife wiper does not drop low enough. 11. No play between forked lever and collar. 12. Metal between mold cap and liners, or between liners and mold body. A remedy is the regular inspection of parts and metal temperatures.

Q. 11. How can you tell when a plunger or "well" is worn?

A. A hollow slug will be cast and the metal will back up in the crucible, due to lost compression. This causes bubbling-up on the surface of the metal in the pot just above the well.

Q. 12. Can old style Linotype plunger be drilled and made to perform like the new style with hole near the bottom and adjustable nut?

A. Yes, by drilling part way through the lower two rings with ⅛″ drill, finishing with a #52 drill. Then tap and fit with new style plunger fittings.

## Monotypes

Q. 1. At what temperature should monotype metal be re-pigged?

A. 725 to 750°

Q. 2. How often should pump body and nozzle be drilled and cleaned?

A. Pump body—twice a week; nozzle—daily.

Q. 3. What causes "spitting"? Remedies.

A. Nozzle not seating properly; square up and center pot. Nozzle may be worn; if so, trim it or renew. Pump body should be lined up with mold. Metal too hot. Avoid too much pump spring pressure.

Q. 4. When pump and piston lever bearings show wear, what should be done?

A. They should be replaced, as to repair them is costly and not always satisfactory in the end.

Q. 5. What will cause piston to stick?

A. Dirty metal. Sudden change of temperature. A new and close fitting piston. Dirty piston. Low metal level causing dross to be worked down.

Q. 6. What causes metal to be forced between "well" and piston?

A. If either the well or piston is worn, this permits the metal to be forced between them.

Q. 7. What causes "fins" or "whiskers" on sides of type?

A. Worn or loose cross block in mold.

Q. 8. What should govern metal temperature and water regulation?

A. Good face and solid type.

Q. 9. What causes hollow type?

A. Worn float valve—improper pump adjustment—spitting—worn pump body—worn levers—not enough spring tension—hole in piston not lining up with porthole.

Q. 10. What causes frosty faces?

A. Too much water; cold metal; dirty pump body and nozzle; too much oil on mold; and nozzle seating in mold too soon.

Q. 11. What causes brittle strip material?

A. All of the answers to Q. 10, plus position of mold blade stroke in relation to nozzle and dirty mold.

Q. 12. What causes squirts?

A. Metal being too hot will cause this and is very common among the operators. Oil will cause a squirt. This gets on the top of the mold when too much oil is used on the mold. If the pump spring is too low or too much tension is on the piston, and bad matrices will cause this trouble. Bridge adjustments, bent centering pin, type thrown on top of mold. Metal being too hot, causing the mold blade to hang up are common reasons why there are squirts. When it is repeated very often, then machine is out of adjustment in some manner.

Q. 13. What causes mold blade to hang up?

A. Dirty mold—mold blade not adjusted properly—overheating mold—poor quality mold oil—lack of oil.

Q. 14. What causes "blisters"?

A. Too much *speed* generally. Minor causes may be excessive temperature, lack of water and too much piston spring tension.

Q. 15. What causes piston (at porthole) to wear?

A. Erosion due to flow of metal. Metal level in pot too low permitting dross to be drawn down between pump body and piston.

## Stereotype Department

Q. 1. When is stereotype metal meeting best the requirements of good stereotyping?

A. Stereotype metal is best meeting the requirements of stereotyping when it is of correct formula, properly alloyed, free from impurities and can be cast between 550° and 625° into solid plates with sharp, even printing surfaces.

Q. 2. (a) At what intervals should dross be skimmed?
(b) Should a flux be used? If so, what kind?

A. (a) Preferably once each week or more often, depending on conditions and quality of metal in use. Allow dross to accumulate to a depth of one inch. This blanket of dross retards oxidation of the supply by protecting it from the air.
(b) Yes, use Vitaflux whenever dross is removed to rid it of any shotted metal and at the same time to re-vitalize the metal in the pot.

Q. 3. At what temperature should skimming be done?

A. 700 to 750 degrees.

Q. 4. (a) What is an ideal analysis for a supply?
(b) What is the best range of casting temperatures?

A. (a) 5% to 5½% tin, and 13¼ to 13¾% antimony.
(b) Make experiment to determine lowest practical temperature with a minimum of water in casting box, usually 550-625 degrees F.

Q. 5. At what intervals and how long should metal be agitated?

A. Before each edition is cast. Metal should be agitated from three to five minutes, depending on type of agitator. The entire mass should be stirred.

Q. 6. Name the symptoms of casting box which needs cleaning.

A. Hot spots or shrinks in one spot all the time; continued poor face regardless of change of water or metal temperature, and slow cooling of a plate are the normal symptoms of a box which needs cleaning. As a precaution, casting boxes should be taken apart and examined once every six months.

Q. 7. Name all causes of surface porousness on plates.

A. The first cause is metal being too hot. Second is continued casting in a box which does not permit it to cool and you have then a hot box. Another cause is cooling the plate too quickly from the back, which causes the porousness to be entrapped in the face. The reverse procedure should be followed, the plates are cooled first on the face and then on the back. A damp mat. Tailpiece too thick.

Q. 8. What is the effect on cast when box is not lined up with mouth of spout?

A. The normal effect is trapped air in the plate because the metal sets too quickly and does not permit the air to get out. In other words, it looks like a hot plate because it will be rather porous and may also be chilled at the same time.

Q. 9. Should the throat of spout be heated in some manner? Why?

A. In most of the new equipment the throat is heated because it permits the metal temperature in the pot to be worked at lower temperature as it keeps the metal hot in going into the box. This is probably due to the fact that the throat is much longer now than it used to be. If the hookup to the pot is very short, it is not necessary to heat the throat.

Q. 10. Cause of (a) sink; (b) chill; (c) hot spot?

A. (a) The usual cause of sink is an improper alloy of metal, impurities, water too cold, cold box, damp mat, metal too hot.

(b) The cause of a chill is a cold box, cold mat, damp mat and cold metal or a mat facing that chills metal.

(c) Hot spot is caused by dirty box or faulty cooling, and also if metal is poured against some spot in box all the time without respite.

Q. 11. Cause of air entrapped under plate surface?

A. Metal too cold; too much water on the box; spout out of line with the box; improper locking of mat in box; pump not working properly; tailpiece too small.

Q. 12. What is considered the ideal relation between water on the box and temperature of metal?

A. By operating at lowest practical temperature with a minimum of water in the casting boxes.

Q. 13. (a) Ordinarily when you increase the water pressure, what should be done with temperature?

(b) Vice versa?

A (a) When water pressure is increased it is necessary to increase the temperature of the metal.

(b) When water pressure is decreased, metal temperature must be lowered.

Q. 14. If the thickness of the plate varies, where would you look for the trouble?

A. The shaver.

Q. 15. Why do you occasionally see a paper tailpiece in use?

A. Paper tailpiece does not cool as quickly as a steel tailpiece. Paper tailpiece will give a more solid plate.

Q. 16. Halftone cuts, to what depth should they be etched in (a) high-lights; (b) middle-tones; (c) shadows?

A. (a) .006″; (b) .0045″; (c) .0035″.

Q. 17. What does the stereotyper frequently do before molding the form to "bring up" a poor halftone cut?

A. All cuts should be underlaid .006″ above type high.

Q. 18. (a) Why should a mat before molding contain some moisture?

(b) Why is this same moisture a detriment when casting?

A. (a) A mat should contain some moisture so that a proper impression can be made into the form without injuring the mat.

(b) The same moisture is a detriment in casting, because it will cause plates to be cast with chilled spots and sinks.

Q. 19. What is the purpose of a tail on a stereotype cast, whether curved or flat?

A. To insure securing sufficient metal for cast; to eliminate porousness on tail of plate; and to secure a more solid cast.

Q. 20. To insure proper control of temperature and cooling of box, what would you recommend?

A. Stereotype pot should be equipped with a pyrometer and automatic heat control. Water line to box should have pressure gauge.

Q. 21. What advantages are claimed for electricity as a fuel?

A. Automatic control of heat; cleaner; no fuel fumes; dependable, as heat is applied directly to the metal, thereby preventing cracked pots; less radiation loss; and lower room temperature.

Q. 22. (a) How would you select a representative sample of a supply for analysis?
(b) Of a pig of new metal?
(c) Why never an ear?

A. (a) Shavings from the Tail Trimmer are best as a stereotype sample. They give particles from many plates and in this manner a representative sample is secured.
(b) A sample of new metal should be selected from the center of the pig, this giving the most representative portion.
(c) Samples from an ear of a pig are undesirable due to the ingredients having a tendency to separate when cooling.

Q. 23. Describe a system for replacing ingredients lost in order to maintain analyses.

A. Metal deteriorates in the form of dross and this loss should be replaced by the Imperial plus metal plan. This is a systematic arrangement by which any user of type metal can maintain the present balance in his mixture by replacing each pound of dross skimmed off the metal during the remelting by an equal weight of plus metal. Plus metal means the original metal, the kind of metal being remelted plus the ingredients that are normally lost into the dross. By replacing a pound of dross with a pound of plus metal, balance is maintained in the supply.

Q. 24. What "screens" in halftones are commonly used for (a) newspapers? (b) magazines?

A. (a) 55, 60 and 65 lines to the inch; (b) 100 to 150; however, 120 to 133 are the most common.

Q. 25. Why is packing used on the back of a mat?

A. Packing is used on the back of a mat to keep the low spots up so that when the cast is made they will be as low as in the original form. It saves routing the plate after the cast.

Q. 26. What is "parting powder" and purpose?

A. Parting powder is a talc formation and its purpose is to cause the mat to release quickly from the casting and at the same time it fills up some fractures in the mat made when molding the form.

Q. 27. Why and when do some stereotypers use oils, glycerine, etc., on the face of mats?

A. Oils and glycerine are sometimes used on the face of a mat to smooth over the fractures caused by molding the form.

Q. 28. For a new stereo plant how would you estimate quantity of metal required?

A. At least $1\frac{1}{2}$ times the capacity of the stereotype pot; double the capacity of the pot if stereo metal is used for flat casting.

Q. 29. Should flat casts be made from lino or stereo metal?

A. Either; though from lino preferably, as no hand-picking of cuts is necessary in plants where material, type and cuts are all from lino. In this way the linotype and stereotype metals are not liable to become mixed.

## Press Room

Q 1. Name the causes for plate breaking on press?

A. (a) Plate only loosely locked on plate cylinder.

(b) Plate locked up too tightly.

(c) Where plate was accidentally dropped and crack or sprung condition resulted.

(d) Worn clips; metal brittle; plates very porous at ends.

Q. 2. What causes ink penetration on newsprint?

A. (a) Excessive heat in press room.

(b) Poor quality oil in ink, in which case penetration will show yellow.

(c) Transparent paper, in which case penetration will show clear.

Q. 3. Better print from slow or high speed?

A. Slower speed better cuts; but good results are obtained from some types of high speed presses, depending on inking mechanism and cylinder construction. A press geared for 36,000 should be run about 28,000 for best results.

Q. 4. What causes mottled appearing solids?

A. Usually light form rollers.

Q. 5. What causes vertical white streaks in solids?

A. Usually poor ink distribution.

Q. 6. What causes horizontal white lines at feet of type?

A. Heavy form rollers.

Q. 7. What causes gray solids?

A. Cuts low in form. Sometimes can be overcome by form roller adjustment or slight increase of impression.

Q. 8. How much impression should be carried in presses in plants using dry mats (figure speed 36,000 per hour)?

A. 0.015 set from standstill; 0.012 set from standstill for Duplex or slower speed presses.

Q. 9. What causes blacking or smeared open spaces?

A. May be (a) shallow molded mat; (b) poor routing of plate; (c) form roller too heavy, or (d) sheet wrinkling over cylinder.

Q. 10. What causes bent head rules?

A. Improper justification of forms; poor column rules; and too much pressure in molding.

Q. 11. What change in composing room will insure longer life to press blankets?

A. Reduce column rule and leader height to .915″.

Q. 12. What causes a generally smeary sheet?

A. Too much ink; plate with shallow depth; worn blankets; or poor rollers.

## General

Q. 1. Describe what you consider an ideal remelting condition.

A. An ideal remelting condition should embrace the following:

a—Pot capacity not less than 500 lbs.; preferably large enough to remelt one day's run.

b—Located on sheet metal floor in a separate well-ventilated and lighted room near the Composing Room.

c—Supervised by Composing Room foreman—preferably the machinist.

d—Bins provided for separate metals to avoid mixing.

e—Stirring, skimming and pigging to be done at the following temperatures: Line Slug Metal, 650 to 675°; Monotype Metal, 725 to 750°.

f—Use of Plus Metal to replace accurately all elements lost in the form of dross.

g—Use of Vitaflux to vitalize the metal and prevent wasteful skimming.

h—Pot well insulated, enclosed and either thermostatically controlled, or equipped with a thermometer to prevent under-heating and over-heating. Bottom pour and water-cooled molds are desirable features, but not essential.

i—It is practically impossible to pour metal in open molds without a certain amount of splashing and agitation, which produces dross on the surface of each pig poured. This dross should be removed immediately after pouring, and before freezing, with a small skimmer in order to secure good clean pigs to feed in your machine.

(Note—We will be pleased to send you a skimmer specially designed for this purpose if you will write us.)

Q. 2. Who, in your opinion, should supervise the remelting operations?

A. Supervision should be vested in the man (preferably the machinist) responsible for the satisfactory performance of the typecasting machines. However, the actual operation should be conducted by some one of sufficient intelligence to carry out simple instructions.

Q. 3. Why is an under-size remelting pot wasteful?

A. An under-size pot does not lend itself to efficient (a) heat control, (b) stirring and skimming, or (c) proper fluxing and the addition of Plus Metal. Also, the metal surface exposed to the air is out of proportion to the small amount of metal in such a pot—hence, excessive drossing results. Usually the same amount of labor, time and fuel will remelt a larger quantity of metal; therefore, it is always better to use a slightly over-size pot than one that is under-size.

Q. 4. What do we mean by Eutectic?

A. Eutectic is the point at which all three elements (lead, tin and antimony) are in perfect solution with one another—the lowest melting point. This occurs in alloys of approximately 4% tin, 12% antimony and balance lead.

Q. 5. If metal deteriorates, describe a system of replacing any deficiency.

A. After an analysis, add to the supply a special alloy compounded to restore the elements to normal, and thereafter replace dross losses at each skimming with an equal weight of Plus Metal.

Q. 6. When is dross normal dross?

A. Dross is considered normal when it is in the form of a dry powder, free of particles of metal. This can be accomplished quite readily by the use of Vitaflux.

Q. 7. What do you consider a representative type metal sample (a) in Linotype? (b) in Monotype?

A. A representative sample of Linotype Metal, weighing 12 ounces, consists of a few sprues taken from each machine in the customer's plant, because this represents an average from many slugs that have been cast. (b) A representative sample of Monotype Metal, weighing 12 ounces, would be a few pieces of type taken from each different operation and of different sizes, so that you might get the average of several different remeltings.

Q. 8. Describe the best type of skimmer to use.

A. The best type of skimmer to use in remelting is one approximately 8″ to 10″ in diameter, made of steel with a handle 44″ to 48″ long. The face of the skimmer proper should be dished to a depth of ¾″ and should be filled with holes about ¾″ apart. This permits any molten metal taken up during the skimming to run through back into the pot and all that is removed is pure, clean dross.

Q. 9. Do you recommend a metal feeder? If so, why?

A. Yes. Metal can be kept automatically at proper level in the crucible without interrupting the operator. Feeder pigs can be cast more rapidly than hand-fed ingots. Pot temperature does not fluctuate, thus contributing to better casts. Finally, increased production should result.

Q. 10. What is the height of (a) Type? (b) Low Quad? (c) Standard base? (d) High Quad?

A. (a) .918″. (b) .763″ on display and .7635″ on composition. (c) .860″ for electros; .868″ for steel variable; .759″ for 11-pt. plate, and .853″ for 16-gauge zinc. (d) .8889″.

## Cautions

DO NOT

Overheat your metal.

Allow zinc in molten metal.

Allow brass in molten metal.

Allow copper in molten metal.

Attempt toning without analysis.

Reclaim metal without purity test.

Attempt to use impure metal.

Agitate metal unnecessarily.

Melt less than capacity of pot.

DO

Skim metal at proper temperature.

Use flux in skimming.

Have analysis made periodically of your metal.

Stir molten metal thoroughly.

Use your thermometer.

Add Plus Metal regularly to keep your supply up to normal.

## Melting Points of Chemical Elements

Supplied by the U. S. Bureau of Standards from latest determinations. These values are the most accurate procurable at the present time. Arrangement is in order of melting points.

| | *Melting Points* | *Specific Gravity* |
|---|---|---|
| Mercury | —38°F. | 13.59 |
| Tin | 450° | 7.29 |
| Bismuth | 520° | 9.80 |
| Cadmium | 610° | 8.60 |
| Lead | 621° | 11.37 |
| Zinc | 787° | 7.15 |
| Antimony | 1166° | 6.71 |
| Aluminum | 1218° | 2.56 |
| Arsenic | 1562°* | 5.67 |
| Silver | 1761° | 10.53 |
| Gold | 1945° | 19.32 |
| Copper | 1981° | 8.93 |
| Nickel | 2646° | 8.80 |
| Iron | 2786° | 7.86 |
| Platinum | 3191° | 21.50 |
| Tungsten | 5430° | 19.10 |

*At a pressure of 15 atmospheres.

## Densities

The densities are taken from the Smithsonian Physical Tables (7th Review Edition).

| *Metal* | *Physical State* | *Density in grams per cm3* | *Temperature* |
|---|---|---|---|
| Lead | Vacuo-distilled . . . . . | 11.342 | 20°C. |
| Tin | Wrought . . . . . . . . | 7.30 | -- |
| Antimony | Vacuo-distilled . . . . . | 6.618 | 20 |
| Mercury | Liquid . . . . . . . . | 13.546 | 20 |
| Bismuth | Vacuo-distilled . . . . . | 9.781 | 20 |
| Cadmium | Wrought . . . . . . . . | 8.67 | -- |
| Zinc | Cast . . . . . . . . . . | 7.04—7.16 | -- |
| Aluminum | Wrought . . . . . . . . | 2.65—2.80 | -- |
| Arsenic | Crystallized . . . . . . | 5.73 | 14 |
| | Yellow . . . . . . . . . | 3.88 | -- |
| Silver | Cast . . . . . . . . . . | 10.42—10.53 | -- |
| Gold | Cast . . . . . . . . . . | 19.3 | -- |
| Copper | Cast . . . . . . . . . . | 8.30—8.95 | -- |
| | Annealed . . . . . . . . | 8.89 | 20 |
| Nickel | . . . . . . . . . . . . | 6.96 | -- |
| Iron | Pure . . . . . . . . . . | 7.85—7.88 | -- |
| Platinum | . . . . . . . . . . . . | 21.37 | 20 |
| Tungsten | . . . . . . . . . . . . | 18.6—19.1 | -- |

## Linear Expansion

The data on the thermal expansion of metals shown below were likewise taken from the Smithsonian Physical Tables.

| *Metal* | *Temperature or temperature range* | *Coefficient of Expansion per °C* |
|---|---|---|
| Lead . . . . . . . . . . . . . | 0 to 100°C | 0.0000271 |
| Tin . . . . . . . . . . . . . . | 0 to 100 | .0000230 |
| Antimony, parallel to axis . . . | 40 | .0000169 |
| Antimony, perpendicular to axis | 40 | .0000088 |
| Mercury . . . . . . . . . . . | 20 | .0001819* |
| Bismuth, parallel to axis . . . . | 40 | .0000162 |
| Bismuth, perpendicular to axis . | 40 | .0000121 |
| Cadmium . . . . . . . . . . . | 0 to 100 | .0000316 |
| Zinc . . . . . . . . . . . . . | 0 to 100 | .0000298 |
| Aluminum . . . . . . . . . . . | 0 to 100 | .0000222 |
| Arsenic . . . . . . . . . . . | 40 | .0000056 |
| Silver . . . . . . . . . . . . | 0 to 100 | .0000189 |
| Gold . . . . . . . . . . . . . | 0 to 100 | .0000147 |
| Copper . . . . . . . . . . . | 0 to 100 | .0000167 |
| Nickel . . . . . . . . . . . | 40 | .0000128 |
| Iron (soft) . . . . . . . . . . | 40 | .0000121 |
| Iron (wrought) . . . . . . . . . | —18 to 100 | .0000114 |
| Platinum . . . . . . . . . . | 40 | .0000090 |
| Tungsten . . . . . . . . . . | 27 | .0000044 |

*Coefficient of cubical expansion.

Landolt-Bornstein Physikalisch-Chemische Tabellen and the following scientific papers of the Bureau of Standards give additional data on thermal expansion.

Scientific Paper No. 410, Thermal Expansion of Copper and some of its Important Industrial Alloys.

Scientific Paper No. 426, Thermal Expansion of Nickel, Monel Metal, Steelite, Stainless Steel, and Aluminum.

Scientific Paper No. 433, Thermal Expansion of a Few Steels.

Scientific Paper No. 497, Thermal Expansion of Aluminum and Various Important Aluminum Alloys.