GPO-PIA JOINT RESEARCH BULLETIN
COMPOSING ROOM SERIES NO. 1

C-1

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Type Metal Formulas in Commercial Printing Plants

In the application and use of type metal there is a variance of opinion concerning formulas. The following type metal formulas have been suggested as representative of those used commercially.

For slug-casting machines including Intertype, Linotype, and Ludlow, also for Elrod and Monotype material machines, the following standard formulations are in use by many plants throughout the United States:

Tin.—A minimum of 4.25 percent up to and including 6 percent.
Antimony.—A minimum of 11 percent up to and including 12 percent.
Impurities.—Total not to exceed 0.10 percent.
Lead.—Balance.

The casting temperatures range from 510° to 560° F., depending upon the size character being cast. Some plants use the following formula for casting large slugs and display faces:

Tin.—6 percent.
Antimony.—11.25 percent.
Lead.—82.75 percent.

For the Monotype, Thompson, and Giant casters, as well as other sort casters, the following standard formulations are in use:

Tin.—A minimum of 7.25 percent up to and including 13 percent.
Antimony.—A minimum of 16.50 percent up to and including 23 percent.
Impurities.—Total not to exceed 0.10 percent.
Lead.—Balance.

The casting temperatures range from 600° to 750° F., depending upon formulation used and character being cast.

For regular speed composition casting on Monotype casters in commercial printing plants for book, catalog, and other volume composition, the following formula is widely used:

Tin.—7.25 percent.
Antimony.—16.50 percent.
Lead.—Balance.
Casting temperatures range from 615° to 675° F.

For printing, copy and display for national advertising, as well as for many other applications requiring fine reproduction from Monotype, Thompson, and Giant casters the following formula is used:

Tin.—9.25 percent.
Antimony—19 percent.
Lead—Balance.
Casting temperatures range from 625° to 700° F.

In advertising-typographer plants this monotype formula is recommended for reproductions on etch proofs, cellophane, hard enamel stock, and patterns for plates.

Where Thompson and Giant casters are used in making foundry type, the following standard formulation is extensively used:

Tin.—13 percent.
Antimony.—23 percent.
Lead.—Balance.
Casting temperatures range from 600° to 750° F.

In addition to being used for casting foundry type, it is used on Monotype casters for display sorts and for Intertype and Linotype machines with special hard metal attachments for special large city telephone and long-run directory work.

In the process of stereotyping in contrast to monotype and slug-casting the metal is cast in plates of much larger volume and weight and is not required to pass through a small casting orifice. The formulas vary, depending upon the end-use of the stereotype plate.

Stereotype formulations for use in fine-screen book work, color magazine, cellophane, color comics, patterns, and newspapers range as follows:

Tin.—6 percent minimum, 12 percent maximum.
Antimony.—12 percent minimum, 14 percent maximum.
Lead.—Balance.
Casting temperatures range from 510° to 600° F. under normal conditions where drafts do not interfere.

For newspapers a formulation as follows is used for black and white and color plates:

	Black and White	*Color*
Tin	6 percent	8 percent.
Antimony	13.50 percent	14 percent.
Lead	Balance	Balance.

Casting temperatures range from 535° to 600° F.

For book work, fine-screen job, flat and curved, black and white or color:

Tin.—8 percent.
Antimony.—14 percent.
Lead.—Balance.
Casting temperatures range from 510° to 550° F.

For special color work, hot curving, and cellophane printing:

Tin.—12 percent.
Antimony.—12 percent.
Lead.—balance.
Casting temperatures range from 510° to 535° F.

There are still many special formulations in use, but the above are accepted standards and used by many plants.

Type metal is a basic factor in the final appearance of a printed reproduction and in production costs in all printing plants.

Type Metal Impurities

Impurities in type metals are those elements or oxides present in such quantities as to be considered undesirable or definitely harmful to the type or the casting machine. The impurities most likely to occur in type metal supplies are zinc, copper, nickel, arsenic and oxides of the lead, antimony, and tin constituents. Aluminum may sometimes be present.

Zinc and copper are most easily introduced accidentally into type metal stocks because of the presence in most printing establishments of zinc and copper engravings, and copper and zinc in brass slug-casting matrices. Routing and sawing of these metals produce dust or chip scraps which, unless carefully segregated, contaminate the type-metal stock in the next remelting.

Zinc, which has a relatively low melting point (787° F.), greatly increases the surface tension of the molten type metal which it contaminates, resulting in a sluggish consistency having poor flowing quality and castability. Zinc must be entirely absent from type metal.

Copper which has a melting point of 1,981° F. forms needlelike crystal compounds with tin and antimony which are insoluble at the usual casting temperature (525° to 550° F.) of the slug-composing machines. These tend to accumulate and eventually to clog the mouthpiece nozzles or orifices of type-casting machines resulting in defective type faces or hollow slugs. This accretion necessitates frequent drilling of mouthpieces to remove the accumulation. Copper has less of this effect on the monotype caster because of the higher casting temperature of 700° to 750° F. (approximately 200° F. higher than on the slug-casting machines.) It is sometimes added as a hardening ingredient to foundry type which has a high tin and antimony content and is also cast at higher temperatures. Copper should be restricted to 0.05 percent or less in slug-casting metal.

Nickel is said to act similarly to copper in type metals. Stereotypes, which are often nickel plated to increase their wear resistance on the press, may serve as a source of nickel for stereotype metal.

Aluminum has been reported to act like zinc and should likewise be absent from type metal.

Arsenic which is usually present in type metals in amounts from 0.01 to 0.15 percent is sometimes mentioned as an impurity but seems to cause no harmful effects in these quantities. Some authorities claim that it is an objectionable impurity in type metals at the operating temperature of the Monotype caster because of its pitting action on the steel pump mechanism. No difficulties of this nature have been encountered at the Government Printing Office. It is said to refine the grain structure of type alloys and increase the hardness. In lead-shot manufacture, 0.3 to 0.8 percent of arsenic is added to increase the fluidity of the metal and give the drops a spherical shape in falling through the air from the shot tower (4).

Oxides or fine dross particles are also considered as impurities in type metal and should be removed by careful stirring and drossing.

Study of Bismuth in Type Metal

The addition of bismuth to tin- antimony lead type-metal alloys was found by Thompson (5) to decrease slightly the tensile strength, hardness, and resistance to compression but to improve somewhat the casting properties.

A study was made of the effect of small quantities of bismuth on stereotype metal. Additions of 1, 2, and 4 percent of bismuth were made to metal of the Government Printing Office standard stereotype-metal formula. A few flat and curved stereotype plates were cast from these metals and compared, at the start and finish of the press runs, with plates on the same jobs cast from standard metal.

No difference either in appearance or wearing quality of the plates could be detected in the case of the 1 percent bismuth addition. In the case of the 2 percent bismuth additions the plates were slightly brighter, a quality which is of some assistance in examining the type faces for defects. Only the plates with 4 percent bismuth additions were run on the press until worn out. They were removed after 60,000 impressions at the same time as similar plates containing no bismuth.

The bismuth additions did not affect casting temperatures to an appreciable extent. A comparison of the plates containing bismuth with the control plates without bismuth showed no difference in sharpness of detail of type faces either before or after the plates were used.

Bismuth in the percentages tested is apparently without significant practical effect in stereotype metal.

The test plates were poured by hand ladle, so that the effect of the bismuth on pump mechanisms was not determined. However, there is no reason to suspect any difficulty in this respect.

Data on the test runs are given in the following table:

Kind of metal	Number of impressions	Kind of paper	Type of plate
Stereotype plus: 1 percent bismuth ...	12, 500	30 percent rag bond.	Flat.
	22, 500	Machine-finish book.	Do.
2 percent bismuth ...	37, 500	Newsprint....	Curved.
4 percent bismuth ...	60, 000	...do........	Do.

Cadmium in Type Metal

The addition of 0.5 to 7% of cadmium to type metal alloys was patented by Yerger and Somers (7). They claimed a cast type having improved casting qualities, lowered casting temperature, and increased hardness.

Remelting and Casting Procedure

The remelting department for used-type metal should be located in a lighted, well-ventilated room, preferably by itself. The equipment should include adequate heavy sheet-iron containers or bins for the type, a furnace of sufficient capacity, with a thermometer and temperature control, and suitable molds.

Many metal problems can be avoided if a conscientious operator inspects the metal and removes harmful substances prior to remelting. If thermostatic controls are not available frequent attention must be given to control the temperature.

Used-type metals returned to the foundry or remelting room should be kept scrupulously clean and contain no dirt, trash, floor sweepings, copper, zinc, or aluminum particles, shavings, or routings. This is an ideal condition not realized without constant emphasis and supervision. It is very important to have a competent workman in charge of remelting operations to insure this attention.

Important factors in the care of type metal alloys are the methods employed to purify the metals, the temperature at which the necessary metals or alloys are added to bring the metal to the desired composition, and the proper alloying and agitation of the corrected metal.

In the Government Printing Office discarded type from the various sections of the Composing Division, and plate shavings, routings, sawings, and trimmings from the Platemaking Division are returned in steel trucks of 1,000 pounds capacity to the balcony of the remelting room. There each kind of metal is dumped on an endless belt conveyor which empties it through chutes to fill the furnaces by gravity. Great care is taken to avoid any mixing of different type metals for reasons of economy.

Stereotype and electrotype plates because of their size and weight are placed in the remelting pots manually instead of by the conveyor and chute means.

Each of these furnaces, four of eight tons and one of five tons capacity, is heated with gas and equipped with automatic temperature control and an indicating pyrometer. This is important to avoid overheating the metal.

The discarded metal which has been transferred to each pot is melted down and additional metal added and melted until the desired volume level is obtained and the temperature has reached 600° F. The bulk of the unmelted loose type or plates considerably exceeds that of the metal after it has become molten.

A type metal operator whose work shift starts at 5 a. m. has the metal melted and at the proper volume by 8 a. m. when the full day shift begins.

At 600° F. the metal is thoroughly stirred by a motor-driven device,[4] and a flux consisting of a mixture of equal parts of sal ammoniac, rosin, and carbon black is added by scattering it over the metal surface with vigorous stirring to reduce the dross to a minimum. The dross is then removed by skimming with a perforated dipper which permits the molten occluded metal or "shotted metal" to escape. It is then transferred to dross drums. After the dross is removed and the metal is thoroughly stirred, the distance from the surface of the molten metal to the edge of the pot is measured, and by prior calibration the weight of the contained type metal is determined. This must be known because it is the basis on which adjustments of composition are made. An 8-ounce sample is poured and sent to the laboratory for analysis and calculation of the necessary additions of correction metals or alloys. The temperature is then raised to 700° F. and the correction metals are added to the molten metal in

[4] For many years agitation of the molten metal was provided by filling an iron cage having approximately 1 cubic-foot capacity, with green oak wood and forcing this to the bottom of the pot by a chain-and-pulley device. This green wood provided a vigorous agitation of gases which exerted a reducing or deoxidizing action. However, the use of green oak wood agitation has been replaced by motor-driven stirrers to reduce the evolution of smoke and fumes.

the pot in the required amounts as determined by the analysis of the sample.

After the correction metals have melted and have been thoroughly mixed into the type metal, it is again treated with flux and the dross removed as described above.

The corrected molten metal is poured into water cooled molds by means of a centrifugal pump which has a rheostat to provide adjustable control of the rate of pouring with a trigger device for starting and stopping the flow of the metal. It is then poured through a strainer to further eliminate any dross or coarse particles. The ingots or "pigs" solidify in approximately 3 minutes and are dumped onto skids which hold 80 pigs, or approximately one ton each.

A safety development in the molds provides a narrow open end or "slotted eye" ingot, the end of which drops into the melting pot on the casting machine by gravity. Manual removal of this small hot "eye end" is thus avoided.

By this procedure 8 or 9 tons of metal can be cast into 25-pound ingots in 2 hours by two operators. When cool, these type metal pigs are delivered to the Composing and Platemaking Divisions, using a semiautomatic lift truck for hauling.

Dross

When type metal is melted, there is always a small amount of material which does not enter the liquid metal, but remains on the surface of the metal. The general name for this material is dross or skimmings. There are two chief classifications for dross: first, a dross which is on or in the metal before melting; second, a dross which is the result of oxidation of the essential constituents of the metal while molten.

The first kind of dross which is in suspension in the type metal before it is melted consists of a fine dispersion of sulfides, arsenides, copper, or other metals and metallic compounds not soluble in type metal at the ordinary working temperatures. If the temperature is not as high as is required to melt clean type metal of that particular composition, there may be a segregation of antimony or antimony and tin compounds. These materials will separate to the surface as a pasty or wet skim. They do not separate as pure constituents, but retain several times their weight of the alloy. For this reason, the dross when skimmed and cooled frequently has the appearance of metal on the surface.

The second kind of dross does not exist as such in the original metal. It is formed by oxidation. As tin oxidizes more readily than lead or antimony, this oxide contains a higher portion of tin than the original metal. This dross forms at the surface of the metal, has a dark color when produced at low temperatures, and a yellow color when produced at high temperatures. It is drier and more powdery than the first kind of dross. This dross may also retain occluded portions of the alloy.

In a dross skimmed below 600° F. without flux, the major constituent will be fine metal shot, which may be present to the extent of 80 percent. A flux is recommended for use with the dross that is on top of the pot of molten metal. As the name implies, its purpose is to make the dross fluid. Fluxes dissolve the oxides present in the dross and release the metallic portion so that it can be returned to the bath of molten metal. The normal purpose of a flux is not to change the character of a metal, but to reduce the amount of dross.

The composition of type metal alloys changes after continued use in casting, melting, and recasting, due to loss of certain metals by oxidation or drossing and by contamination with other metals. There is a continual loss in the amount of type metal due to drossing.

An investigation was conducted in the Government Printing Office to determine the normal losses by drossing of the respective type metals, the composition of various type metal drosses, and the best method to reduce dross losses to a minimum.

Type metal dross is composed mainly of the oxides of tin, antimony, and lead, together with any impurities removed in the process of drossing, and more or less dirt from sweepings around the machines and metal pots. The amount and composition of the dross from each kind of metal varies somewhat from day to day. About 80 to 85 percent of the weight of dross can be recovered as metal by reduction processes.

The results of handling type metal alloys in this Office indicate that the loss in slug-casting metal due to drossing occurs almost entirely in the remelting process. The melted metal on the slug-casting machines has only a small surface exposed to the air and is seldom heated to a temperature where any appreciable dross would be produced.

Actual tests on a newspaper remelting pot not equipped with automatic temperature control and operated by an unskilled laborer, indicate that temperatures as high as 900° and 950° F. may occur and that the average temperature was nearer 700° than 600° F. The higher the temperature of type metal, the longer it is kept at this temperature, and the more it is agitated, thus exposing a greater surface to the air, the more dross will be produced.

Slug-casting metal should not be heated above 600° F. unless necessary on account of the addition of a considerable quantity of correction metals. The temperature should be automatically controlled and the remelting pot equipped with an indicating pyrometer. In the removal of dross from slug-casting and stereotype metal in the remelting pot, the skimming is done at 600° F. to reduce to a minimum the amount of shotted metal included in the dross. The preferred temperature range for casting slug-casting metal into ingots is from 550° to 600° F.

Monotype metal contains a higher percentage of tin and antimony than slug-casting metal. This necessitates a much higher temperature on the monotype-casting machines than on slug-casting machines, which will produce some dross on the casting-machine pots. However, in remelting monotype metal the same precautions in the control of the temperature should be taken as for slug-casting metal. For monotype metal the remelting temperature should not exceed 750° F. and it should be skimmed and poured between 650° and 700° F.

Monotype has the highest percentage of straight dross because of the small average size of the type and therefore the relatively large area and because of the high casting temperature. The rapid movement of the monotype pump piston of approximately 150 strokes per minute also increases the amount of dross formed as compared with the pump plunger on the slug-casting machine which casts only about six or seven times per minute for the average composition-type sizes.

In the skimmings from stereotype casting pots there will be more unoxidized metal than in the skimmings from the slug-casting or monotype remelting pots. This is due to the fact that stereotype metal is used at a temperature near the "freezing" point, which results in a slushy condition on the surface of the pot.

Temperature control on stereotype pots is advocated the same as on slug-casting and monotype remelting pots in order to prevent unnecessary overheating of the metal.

Stereotype plates, which are relatively large, often weigh from 2 to 10 pounds or more and have the lowest percentage of dross, when remelted.

It is the custom in many plants to "burn off" the dross by igniting and stirring such materials as animal fats or oil, mineral oil, vegetable oils, or mixtures of these with other materials on the surface of the remelting pots. Carbonaceous material such as molasses residues is sometimes present in mixtures used for this purpose and may prevent to some extent the oxidation of the surface metals. The heat from the burning oils probably aids in separating the unoxidized metal from the dross.

An investigation was made to determine materials best suited for this purpose. Among the materials tested were beef tallow, mutton tallow, molasses residues, lard oil, light lubricating oil, and palm oil. Each of these was used on the remelting pots for a period of two weeks, and a record kept of the amount of dross in each case. The temperatures were kept uniform and it was therefore possible to draw definite conclusions as to the relative value of the various materials in eliminating "shotted" metal and preventing surface oxidation, thereby aiding in reducing the dross.

The materials listed below were burned on the surface of slug-casting metal at a temperature of 600° F. just prior to skimming. The quantity of each material used was approximately one-third of a quart for each 5-ton lot of metal. The percentage of dross also includes the dross removed the following morning after the metal was allowed to cool slowly overnight to permit the copper to come to the top.

Number of lots tested	Material	Percent dross	Number of lots tested	Material	Percent dross
12	Light machine oil.	0.78	12	Castor oil..	0.84
12	Mutton tallow.	.80	12	Beef tallow..	.86
20	Japan wax....	.81	12	Palm oil...	.88
12	Lard oil......	.82			

There is apparently no material difference in the comparative value of these oils.

Sal ammoniac and rosin are frequently used as deoxidizers when ignited or stirred on top of the molten metal.

Sulfur treatment is sometimes resorted to for removal of an excessive copper impurity in the type metal. This is not a desirable operation for the printer. A heavy dross loss results and attention must be given to the removal of obnoxious fumes given off as well as to eliminate from the metal all traces of sulfides which are reported to cause sluggishness and faulty type even when present in small percentages.

In the past when the copper content of a type metal in the Government Printing Office exceeded the maximum permitted, it was treated with sulfur. Six to eight pounds of sulfur were wrapped in a rag and placed in a metal cage which was forced to the bottom of the pot. Sulfur combines with the copper as well as with the other metals to form sulfide compounds which rise to the surface, where they are removed by skimming. The temperature of the metal was lowered to 525° F. for 1 hour for the copper-removal procedure, the dross formed was removed, and the temperature then raised to 700° F., while the correction metals were added and mixed thoroughly.

Records of the Government Printing Office show that on the average cycle from remelting room to the casting machines to the remelting room, the following dross loss occurs in type metals:

	Percent
Slug-casting	1.25
Monotype	2.0–3.0
Stereotype plates	0.5
Electrotype plates	[1] 15.0

[1] Includes copper shells and adherent dross.

It is the practice of the Government Printing Office as well as commercial plants to apply all dross for credit allowance on purchases of new type metals or of correction alloys which are used in bringing type metals up to the standard formulae.

Correction Metals

The addition of correction metals or alloys to molten type metal should be made when the temperature is 700° F., high enough to insure rapid solution.

Formerly a tin-antimony alloy containing 33 percent tin and 67 percent antimony; a lead-antimony alloy consisting of 60 percent lead and 40 percent antimony; grade A lead and grade A tin were used for standardizing type metal. All antimony added to type metal was introduced after it had been alloyed with lead or tin. Wartime restrictions on metals required some modification of these alloys.

Tin-antimony alloy as now used consists of 30 percent tin, 60 percent antimony, and 10 percent lead. Where antimony only is required, metallic antimony is now introduced and alloyed directly with the molten type metal. Tin-antimony lead alloy of this composition is particularly efficient for correction of monotype metal which requires a consistent correction of 0.3 to 0.4 percent tin and 0.6 to 0.8 percent antimony due to dross losses and mixture with other metals after each casting.

Following are five points which should be remembered in remelting and cleaning of type metal:

1. Do not leave the pot unattended, running the risk of overheating and losing the rich constituents.
2. Follow the instructions and temperatures recommended by the refiner supplying the new metal and dross replacements.
3. Be careful that copper and zinc sawings or other impurities do not become mixed with the type metal sawings being returned to the remelting pot.
4. Stirring the metal is very important. Every pot should be thoroughly stirred from 10 to 20 minutes.
5. Use a flux to reduce the dross to a powdery form.

Chemical Analysis

A chemical analysis at regular intervals of each type metal stock in use is necessary as an aid in maintaining the quality to the standard formula.

A representative sample of the type metal to be analyzed should be carefully prepared in a finely divided state suitable for weighing. This may consist of drillings, sawings, or filings from a cross section of an ingot, type, slug, or plate.

The procedure employed in the Government Printing Office for the analysis of type metals is here outlined.

Weigh three 1-gram samples and transfer each to an Erlenmeyer flask, two of 500 milliliters and one of 250-milliliters capacity. To each of the large flasks, add 15 milliliters of sulfuric acid and 3 grams of potassium sulfate, decompose the samples over gas burners and cool. To the small flask, add only 5 milliliters of sulfuric acid and treat as above. This sample is used for copper determination.

To the first flask, add 150 milliliters of distilled water and 20 milliliters of hydrochloric acid and heat the solution to just boiling. Cool to 10° to 15° C. (50° to 60° F.) in a cold water bath, and determine the antimony by titration with a standard solution of potassium permanganate (approximately one-tenth normal).

To the second flask, add 150 milliliters of distilled water, 70 milliliters of hydrochloric acid and 1 gram of finely powdered antimony metal (200 mesh and finer). Connect the flask with a device to pass a stream of carbon-dioxide gas through it continuously. Heat the contents of the flask and boil over a gas burner for 3 to 5 minutes to reduce the tin present in the sample. Cool to 10° to 15° C. (50° to 60° F.) and determine the tin by titration with a standard solution of iodine (approximately one-thirtieth normal) using starch solution as an indicator.

To the third flask (250 milliliters) add 20 milliliters of distilled water and cool. Make the solution alkaline by adding ammonium hydroxide in slight excess and increase the volume to 55 milliliters by the addition of water. Cool the solution to room temperature, filter into a 50-milliliter Nessler color-comparator tube through a dry filter paper and make up to exactly 50 milliliters. Determine the copper value of the sample by color comparison with standards in similar tubes, containing known quantities of ammoniacal copper sulfate.

Calculate the necessary additions of tin, antimony, lead, or of lead antimony or tin antimony alloy on the basis of the tin and antimony content of the sample, as determined by chemical analysis.

This correction data is immediately forwarded to the foreman of the Metal Section who supervises the additions to each pot of molten metal.

About 2 hours are usually required for the analysis of four pots of type metal and calculation of the necessary additions.

Specifications for New Metal

Following are the specifications for the purchase of new type metal alloys and correction metals for use in the Government Printing Office:

Slug-Casting Metal

Tin.—Not less than 4 nor more than 4.5 percent.

Antimony.—Not less than 11.5 nor more than 12.0 percent.

Copper.—Not more than 0.05 percent.

Zinc.—None.

Lead.—Remainder.

To be delivered in Margach ingots, each to be suitably identified and approximately 25 pounds in weight.

Monotype Metal

Tin.—Not less than 7 nor more than 7.3 percent.

Antimony.—Not less than 16.5 nor more than 16.8 percent.

Copper.—Not more than 0.05 percent.

Zinc.—None.

Lead.—Remainder.

To be delivered in Margach ingots, each to be stamped with the word "Monotype" and approximately 25 pounds in weight.

Stereotype Metal

Tin.—Not less than 6.5 nor more than 7.0 percent.

Antimony.—Not less than 12.75 nor more than 13.0 percent.

Copper.—Not more than 0.05 percent.

Zinc.—None.

Lead.—Remainder.

To be delivered in pigs, each to be stamped with the word "Stereotype" and approximately 25 pounds in weight.

Electrotype Backing Metal

Tin.—3.5 percent.

Antimony.—3.5 percent.

Copper.—Not more than 0.05 percent.

Zinc.—None.

Lead.—Remainder.

To be delivered in pigs, each to be stamped with the word "Electrotype" and approximately 25 pounds in weight.

Tin

Federal Specification QQ–T–371a.

Grade A tin—99.85 percent minimum.

To be delivered in ingots weighing approximately 3 pounds each.

Antimony

Antimony.—99.8 percent minimum.

Impurities.—No single impurity shall exceed 0.1 percent.

Arsenic.—0.05 percent maximum.

To be delivered in ingots of 40 to 55 pounds each.

Lead

Federal Specification QQ–L–171.

Grade A lead.—99.9 percent minimum.

To be delivered in ingots of 100 pounds each.

Tin-Antimony Alloy

Tin.—33.0 percent minimum.

Copper.—0.05 percent maximum.

Zinc.—None.

Total Impurities.—0.5 percent maximum.

Antimony.—Remainder.

To be delivered in small ingots weighing 2 to 5 pounds each or in groups of such ingots.

Tin-Antimony Alloy
(War Emergency Specifications)

Tin.—30.0 percent minimum.

Antimony.—60.0 percent minimum.

Copper.—0.05 percent maximum.

Zinc.—None.

Total Impurities.—0.5 percent maximum.

Lead.—Remainder.

To be delivered in small ingots weighing 2 to 5 pounds each or in groups of such ingots.

Lead-Antimony Alloy

Antimony.—40.0 percent minimum.

Copper.—None.

Zinc.—None.

Total Impurities.—0.5 percent maximum.

Lead.—Remainder.

To be delivered in small ingots weighing 2 to 5 pounds each or in groups of such ingots.

Glossary

Brinell Hardness Number. A number indicating the hardness of a material, in this instance of type alloy, determined by a ball of 10 millimeters diameter, under a load of 500 kilograms, applied to a sample of the alloy for one minute.

British Thermal Unit (B. T. U.). The quantity of heat required to raise the temperature of 1 pound of water 1° F., at or near its maximum density of 39.1° F.

Capillary. Having minute tubes or interspaces.

Cassiterite. An important mineral source of tin, consisting of tin oxide.

Centigrade. Indicated by C. A thermometer used in scientific work on the scale of which the interval between the two standard points, the freezing point and the boiling point (at 760 mm. barometric pressure) of water, is divided into 100 parts or degrees.

Centrifugal. A force which impels a thing or parts of a thing outward from a center of rotation.

Correction Metals. Adjusting or toning metals added to type alloys to restore them to the desired standard formula.

Dendrites. Crystals having branching, treelike form.

Dross. Scum which forms in process of melting metals.

Element. Matter which cannot be separated into two or more substances. Thus antimony, lead, and tin are elements; a mixture of them is an alloy.

Eutectic. The lowest melting point of an alloy composed of metals of different melting points.

Fahrenheit. Indicated by F. The Fahrenheit thermometer on which, under standard atmospheric pressure, the boiling point of water is at 212° and the freezing point at 32° above the zero of its scale.

Fluidity. The quality of being capable of flowing.

Flux. An addition of some substance in melting metals for the purpose of separating the impurities as slag.

Foundry Type. Type produced by manufacturers for use as material in typography set by hand.

Freezing. The process of changing a liquid substance to solid form.

Galena. A mineral consisting of lead sulfide, which is the principal source of lead.

Hardness. See Brinell Hardness Number.

Latent Heat of Fusion. The amount of heat which must be supplied at the melting point to a unit quantity of a solid in order to transform it into a liquid at the same temperature (usually at standard pressure).

Matte. An impure product consisting of a mixture of sulfides of metals such as iron, lead, and copper with small amounts of other metals resulting from smelting operations.

Melting Point. The temperature at which a solid substance begins to change from solid to fluid form, specifically when under standard pressure.

Monotype. Pertaining to alloys used in connection with the Lanston Monotype machine.

Occluded. A substance taken in and retained.

Orifice. An opening of relatively small size through which a substance may pass.

Oxide. A combination of oxygen with an element, such as lead or tin.

Segregation. The separation of constituents during the freezing of an alloy which causes local variations in the composition of the solid alloy.

Slug-Casting Machine. A line-casting machine, such as the Intertype, Linotype, and Ludlow.

Specific Gravity. The specific gravity of a metal is its weight compared with the weight of an equal volume of water at the maximum density of water; that is, at 4° C.

Specific Heat. The amount of heat required to raise a unit mass of a substance 1° of temperature at either constant pressure or constant volume.

Stibnite. A mineral composed of antimony sulfide, which is the chief source of antimony.

Surface Tension. That property due to molecular forces which exists in the surface film of all liquids which tends to bring the contained volume into a form having the least superficial area.

Thermal Conductivity. The quantity of heat passing in unit time through a plate of unit area and unit thickness with a temperature differential of 1° between the faces of the plate.

Viscosity. The resistance offered by a fluid to flow.

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NOTE

This is one of a series of pamphlets making available the results of the cooperative research and operations program now carried on by the Government Printing Office and Printing Industry of America, Inc.

These reports of tests and studies being made and projected will provide a reference library covering many technical and operational phases of the printing industry. It is, therefore, suggested that they be filed in a binder or in some other permanent manner which would assure preservation and ready accessibility. Indexes will be provided as developments warrant.

TYPE METALS was prepared by Morris S. Kantrowitz and Clarence L. Buck, as a result of research in the Government Printing Office, and William C. Roddy, who supplied information based upon technical data provided by the Metals Refining Co. Division of the Glidden Co. It has been reviewed and approved by Printing Industry of America's research committee, consisting of Frank F. Pfeiffer, *Chairman,* William G. Albrecht, Jr., James R. Brackett, Stanley C. Hlasta, Russell J. Hogan, Joseph M. Siegel, Bernard Snyder, and Francis E. Street.

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Type Metals

TYPE METALS,[1] together with paper and ink, are the essential materials used by the modern letterpress printer.

The dictionary defines "Type" as something that represents or symbolizes something else; an image. "Type Metal" is defined as—the alloy from which type is made, usually of lead, tin, and antimony in various proportions.

Though carved wooden type probably preceded metal type, Oswald (3)[2] indicated some doubt that it was actually used. Movable hand-cast metal type was used until near the end of the nineteenth century. It was poured into punched molds of sand, metal, or clay but was essentially like the machine-cast type of today.

Type-casting machines were developed in 1885–87. Since then machine-cast type has practically displaced that produced by earlier methods.

The primary constituents of all type metals are lead, antimony, and tin. Small amounts of other materials may be present intentionally or incidentally and they influence the behavior of the metal.

Lead, antimony, and tin have been used in type-metal alloys for several centuries. Records of the Rivoli Press (3) of Florence, Italy, indicate that in the fifteenth century these three metals were the main ingredients of type.

The principal reasons for using alloys of lead, antimony, and tin are their low solidification temperatures, good castability, ease of manipulation and relative cheapness.

The relatively low solidification temperatures of these alloys, which range from approximately 463° to 500° F., lower heating costs, reduce the time interval required for cooling the cast type and lessen the corroding influence on the face of the matrices.

The quality of good castability possessed by these alloys is valuable. They flow readily, when molten, into the fine recesses of the molds to form very sharp reproductions of the matrices. The alloys contract approximately 2 percent by volume upon solidifying.

Zinc alloyed with 6 percent aluminum and up to 1 percent copper has been suggested as a stereotype alloy (1). It is physically harder than the lead base alloys which is advantageous. However, it has a casting temperature approximately 300° F. higher than the ordinary lead-antimony-tin alloys which has kept it from general use.

In this country a different metal formula is used ordinarily in each of the processes of monotype casting, slug casting, stereotyping, and electrotype backing.

The type-casting machines include the Linotype, Intertype, and Ludlow, which cast slugs of type of column or page width, and the Monotype which casts unit type characters.

The slug-casting machines operate at a casting temperature of 525° to 550° F. The Linotype and Intertype slug-casting machines are used chiefly for book work. Most newspaper and magazine work is originally slug-cast and is duplicated by stereotype plates for newspapers or by stereotype or electrotype plates for magazines. The Ludlow casting machine is used for display type and job work.

The Monotype casting machine casts different sizes of unit type and operates at a temperature of 675° to 750° F. It is also used principally for tabular matter, and for highly technical composition.

Properties of Lead, Antimony, and Tin

Lead, the major constituent of type-metal alloys, forms from 60 to 94 percent of type-metal composition. Large deposits of lead are worked in southern Missouri, in Idaho, and in Utah. The lead occurs chiefly as galena, which is a mineral consisting of sulfide of lead.

Lead is described as a blue-gray metal which is bright when freshly scratched but soon clouds over, owing to the formation of lead oxide. It is quite soft and can readily be scratched by a fingernail. Its specific gravity is 11.34 and its melting point 621° F. Lead is one of the heaviest metals known.

Antimony is the second main constituent and forms from 3.5 to 25 percent of the type-metal composition. Small quantities of antimony are produced in Texas,

[1] Strictly speaking these printer's metals should be called type-metal alloys, since a metal is a single chemical element while an alloy is a combination of a metal with one or more other metals, or, as in steels, with a metalloid such as carbon. However, according to common usage, a metal is defined as any substance having metallic properties.

[2] Numbers in parentheses designate the bibliographical references on page 16.

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but the bulk of it is imported from Mexico and China. It occurs usually as stibnite, a mineral consisting of antimony sulfide. Antimony is a silvery-white, brittle, and hard metal having a high luster. It has a specific gravity of 6.68 and a melting point of 1,167° F., which is the highest of the three main type-metal components. Pure antimony has the property of expanding upon solidification. However, the low antimony content in type metals serves to counteract the shrinkage which otherwise would take place, and it is said to also promote fluidity.

Tin is the third constituent of type-metal alloys and is the smallest percentage ingredient, varying from 3 to 15 percent. There are no important commercial deposits of tin in the United States, but large quantities are imported from the Malay Peninsula, Netherlands India, Bolivia, and China. Tin occurs most frequently in combination with oxygen in a mineral called cassiterite which, when pure, contains about 78 percent of tin. One of the highest grades or brands of refined tin, averaging 99.9 percent tin, is known as Straits tin, from the district where the ore is mined in the Straits Settlements of Malay.

Tin is a white, lustrous metal, quite malleable and can be cut with a knife. It has a specific gravity of 7.30 and a melting point of 450° F. It is the most expensive of the type-metal constituents. Briefly, lead contributes cheap bulk, antimony contributes hardness and fluidity, and tin contributes fluidity and lowers the melting point of the metal. Tin also adds hardness when combined with antimony.

The term "eutectic," meaning lowest melting, is applied to the alloy composition, to the solid mixture, and to the temperature of solidification (2).

The eutectic composition of type-metal alloys, as determined by Weaver (6) consists of 4 percent tin, 12 percent antimony and 84 percent lead. This is also known as the ternary eutectic, because three metals are involved. Like a pure metal, the eutectic composition solidifies at a constant temperature instead of over a range of several degrees. The type metal eutectic temperature is 463° F. (239° C.). If tin or antimony is present in percentage greater than the eutectic composition, a compound is formed having a lower specific gravity and greater hardness than the eutectic composition. The cubical crystals of this compound are embedded throughout the eutectic and increase the hardness of the alloy. Thus a monotype metal, having a composition of 16.5 percent antimony, 7.0 percent tin, remainder lead, has a greater hardness than slug-casting metal of eutectic composition.

Lead-antimony-tin alloys, except the eutectic, tend to segregate, due to differences in specific gravity while in the "pasty" range, when some constituents are liquid, others solid. The slower the cooling rate, the larger is the crystal size. Therefore, to restrain this effect, the casting temperature of the type metals is generally kept within 100° F. of the melting-point temperature. The molds into which the metal is cast are cooled, usually by water but sometimes by air as in the vacuum stereotype-casting boxes used in the Government Printing Office.

Physical Properties of Type Metal Alloys

Inasmuch as type metals have to be heated, melted, and cooled again in the course of their use, it is well that type-metal users should have an understanding of the thermal and other physical properties of the type-metal alloys and the metals which compose them.

The specific heat of a metal may be defined as the amount of heat required to raise a pound of the metal through 1° F. and expressed in British Thermal Units. It is a constant for each metal or alloy but differs for various compositions of metals.

Another important thermal property of type metal is the latent heat of fusion. When a pure metal or eutectic reaches the melting point and begins to melt, the temperature remains constant until all of the solid metal has become liquid. The heat absorbed during the melting is a fixed quantity for that metal. The same quantity of heat is released when the metal freezes. This latent heat of fusion has a very important bearing on the flowing characteristics of a metal.

The ability of metal to conduct heat varies widely for different metals and varies for the same metal at different temperatures. Conductivity at temperatures near the melting point has an important bearing on the casting quality of the metal.

All type-metal compositions contract when cooling. The state of cooling, which is of most interest to type-metal users, is the cooling from the liquid to the solid state. Alloys shrink much less when passing from the liquid to the solid state than the average shrinkage of the components.

The thermal properties affect the speed of operation of the casting machines and also the flowing quality of the metal. Factors affecting the speed of operation are the range of temperature between the melting point and the freezing point and, to some extent, the latent heat and the conductivity.

The flowing quality of a metal is also related to a number of factors, among which are the temperature of the metal when delivered to the mold, the freezing range, the latent heat of a metal, its specific heat, the thermal conductivity, the temperature of the mold, and the surface tension of the metal as affected by impurities such as zinc, arsenic, and copper. These, together with the velocity with which the metal strikes the face of the matrix, and the speed with which it freezes after striking the surface, are the most important conditions for overcoming the resistance of molten metal to entering a space of capillary dimensions.

The temperature of the metal as delivered to the mold must be sufficiently above the melting point to permit the metal to flow freely. This temperature should be determined experimentally for any set of conditions.

A metal of long freezing range must be operated at a higher temperature so as to have the same fluidity as a metal of short freezing range. This will slow the operation of the machine.

The latent heat affects the rate of cooling of the metal. If more heat has to be absorbed into the mold from the metal, before the metal is frozen, it will take longer to freeze. If a metal of long freezing range drops below the melting point before it reaches the mouthpiece or other orifice, the constituent which first freezes out may attach itself to the walls of the orifice and restrict the flow. Antimony which separates in irregular dendrites will attach itself more readily than antimony-tin crystals which are cubical. As soon as the first constituent begins to separate, the viscosity will be increased. The shape and size of the primary crystals influence the flow. The increased viscosity and reduced flow, due to restriction of orifice, will reduce the effective pressure and velocity at the critical point of the type, and thus surface tension is not sufficiently overcome and detail is lacking.

The metals used for type have very little elasticity, but are easily deformed by pressure and will stand considerable deformation before they break. In discussing hardness, there are taken into account the elastic limit, the yield point, and the breaking point. These properties may be thought of in connection with tension, compression, or bending. In type metals these points are not so well defined as in iron or in other hard metals. In type-metal alloys the hardness is generally expressed in terms of Brinell hardness number. In the Brinell hardness machine, a ball of 10 millimeters diameter, under a load of 500 kilograms, is applied to a sample of metal for 1 minute. The diameter of the resulting indentation varies with the hardness and is used in the calculation of the hardness number. The harder the metal the greater is the number. Facilities for determining Brinell hardness are usually available in college and university or commercial testing laboratories.

The Brinell hardness numbers of typical commercial printing metals are as follows:

	Brinell hardness No.
Slug-casting metal	22
Stereotype metal	23
Monotype metal	26
Hard foundry metal	32

The hardness of type metal depends upon several factors such as conditions of casting and the composition of the metal. Hardness figures should be accompanied, if possible, by information giving the age of the casting at the time the tests are made as well as the conditions of casting; that is, whether cast with slow or with rapid cooling.

Use of Type Metal Alloys

Unless the formula of a metal is made to function in accordance with the characteristics of the casting machine where the metal is to be used, many expensive operations will be encountered.

The type-metal pigs as produced and supplied by the manufacturer or refiner are used principally by the following:

- Advertising Typographers
- Newspaper Publishers
- Typesetters and Composition Plants
- Stereotype Plants
- Electrotype Plants
- Printers

The metals are used in connection with the various casting machines such as:

Slug-casting metal:
- Intertype
- Linotype
- Ludlow
- Elrod

Monotype metal:
- Monotype Caster
- Monotype Material Making
- Thompson Caster
- Giant Caster

Stereotype metal:
- Automatic Stereotype Caster
- Semiautomatic Stereotype Caster
- Pony Stereotype Caster
- Flat and Curved Hand Casting

Government Printing Office Type Metal Formulas

Owing to the importance of technical control work on type-metal alloys in the Government Printing Office, research was undertaken to determine the best formulas suited for casting of type metal and production of printing plates.

The maintenance of standard qualities of slug-casting, monotype, stereotype, and electrotype-backing metals is essential in order to obtain maximum production of good printing. The value of technical control of type-metal alloys is reflected not only in the Composing Division where the use of uniform standard quality metal results in the maximum production of good composition with a minimum of defective type, but also in the Platemaking Division where stereotype and electrotype plates are produced from the type, and in the Press Division where longer runs of better quality printing will result.

The type-metal formulas used in the Government Printing Office, their casting temperature, and hardness, are as follows:

	Tin	Antimony	Lead	Casting temperature ° F.	Brinell hardness
	Percent	*Percent*	*Percent*		
Slug-casting	4.5	11.5	84.0	525–550	21
Monotype	7.0	16.5	76.5	675–700	25
Stereotype	7.0	13.0	80.0	510–600	22
Electrotype	3.5	3.5	93.0	650	16

SLUG-CASTING METAL

The high tin content of the slug-casting metal in the Government Printing Office when technical control work was started made it more economical to correct all slug-casting metal to 4.5 percent tin rather than to 4 percent tin. Tests made at that time indicated that 4.5 percent tin, 11.5 percent antimony, and 84 percent lead gave very satisfactory results on the slug-casting machines.

In order to determine definitely whether any better results could be obtained with metal of 4 percent tin, 11.5 percent antimony, and 84.5 percent lead, 175,000 pounds of slug-casting metal were experimentally corrected to this formula. This metal was used continuously on eight slug-casting machines for comparison with the results obtained on the other machines using metal of the standard formula of 4.5 percent tin, 11.5 percent antimony, and 84 percent lead. Inspection of the type slugs cast and the action of the metal on the machine showed no apparent difference in the quality of type slugs with either alloy. Therefore, the Government Printing Office adopted as its standard formula for slug-casting metal, 4 to 4.5 percent tin, 11.5 percent antimony, copper impurity preferably below 0.05 percent and not over 0.08 percent, and the remainder lead. The allowable copper content of slug-casting metal has since been set at 0.05 percent, and considerable work has been done to reduce the copper content of this metal, which when metal-control work was begun was above this percentage, in some instances being as high as 0.2 percent. Metal with 4 percent tin content is entirely satisfactory for slug-casting work. Therefore, no attempt is made to hold the tin content of this metal up to 4.5 percent if it falls below this amount. Previous to technical control of type metal the tin content of slug-casting metal was approximately 6 percent.

When technical control work was started considerable trouble was experienced with slug-casting metal which caused clogging of the mouthpiece on the slug-casting machines. Investigation traced this trouble to the fact that air-cooled molds had been put into use for pouring slug-casting metal.

The ingots cast in these molds were approximately 24 inches long and 2 inches square, and weighed about 25 pounds each. After continuous use of these molds in casting ingots, the molds became heated, and the ingots chilled more slowly, producing a coarse-grained metal structure.

Water-cooled ingots solidified in 3 to 5 minutes, whereas air-cooled ingots required 14 to 20 minutes to solidify.

The small amount of copper impurity in the metal formed relatively large needlelike crystals in the air-cooled ingots, aggravating the trouble due to copper. Metal cast in water-cooled molds chilled rapidly and the resulting ingots had a solid close-grained texture and all the crystals, particularly those composed of copper constituents were much smaller than when slowly air cooled.

All air-cooled molds were therefore discarded and all type metals are cast into ingots in water-cooled molds in the type-metal remelting room, in order to secure a finer physical structure.

On the slug-casting machines the cooling of the cast lines is accomplished by means of air- or water-cooled molds. The temperature of the water used for cooling the molds is regulated between 65° and 85° F. This eliminates the variations which may occur on a direct city water line, the temperature of which may vary seasonally from 35° to 85° F. Slugs which are chilled too rapidly because of cold molds become porous or hollow and are therefore defective.

MONOTYPE METAL

The standard formula for monotype metal was set at 7 percent tin, 16.5 percent antimony, and 76.5 percent lead. It was found when technical control was started that the monotype metal contained a higher percentage of copper than the other type metals in the Office. However, since it is cast at considerably higher temperatures, the copper present has caused no trouble, and the percentage of copper originally present has been gradually lowered. From our experience with this metal, copper to the extent of 0.1 percent is not detrimental to monotype metal, but gives added toughness and hardness to the finished type.

Previous to the technical control of the monotype metal, the metal in use by this Office was generally too soft for satisfactory work, due to low antimony content. Further investigations were conducted on different composition alloys for monotype metal. This work was conducted primarily to determine the most satisfactory quality metal to withstand the pressure required in electrotype wax molding. Metal of the standard composition has given satisfactory results in presswork.

Composition of monotype metals tested

Designation of metal	Tin	Antimony	Copper	Lead
	Percent	*Percent*	*Percent*	*Percent*
1—standard....	7.0	16.5	0.25	Remainder.
2............	8.7	18.8	1.10	Do.
3............	6.8	16.1	.30	Do.
4............	9.3	18.1	.80	Do.
5a...........	8.4	19.3	.25	Do.
5b...........	8.4	19.3	.25	Do.
6............	7.9	18.0	.50	Do.

All type was cast at 750° F., except 5b, which was cast at 800° F.

These six monotype-metal alloys were cast on the same casting machine and the same two-column page of six-point type was set with each metal. A careful inspection was made as to the quality of the type cast with each alloy and the pages were then submitted to the Platemaking Division for severe molding tests. As a result of these tests it was found that no better results were obtained with any of the new compositions than with metal of the composition of the standard of 7 percent tin, 16.5 percent antimony, and 76.5 percent lead.

The results from standardization of monotype metal in this Office indicate that a consistent correction is required to keep this metal up to standard.

There is an appreciable loss of both tin and antimony during each cycle of casting, use, and return to the remelting furnace. This may be largely due to mixture with slug-casting metal (which has a lower tin and antimony content) added accidentally, or from pages containing mixed type metals which are difficult to separate thoroughly.

This loss is also due to the high melting point of an alloy of this composition, the temperature maintained on the casting machine being approximately 700° to 750° F., and also to the high antimony content of the alloy. In our correction alloy containing more than 60 percent antimony, a portion of the antimony is present as a mechanical mixture and is not chemically alloyed. The unalloyed metal will tend to rise to the surface of the molten metal and be skimmed off with the dross. At 750° F. temperature there will also be an appreciable loss by oxidation of the metal exposed to the air on the surface of the pot.

Slug-casting metal does not show loss of tin and antimony to the same extent after remelting and may even show a gain if admixture with monotype metal has occurred.

The standard composition adopted for monotype metal is 7 percent tin, 16.5 percent antimony, not more than 0.1 percent copper, and the remainder lead. For type cast for special use or for intricate type faces, where additional hardness is desired, a composition of 9 percent tin, 19 percent antimony, not more than 0.1 percent copper, and the remainder lead has been used in the past.

STEREOTYPE METAL

The formula first adopted for stereotype metal was 8 percent tin, 15.5 percent antimony, and 76.5 percent lead.

Trouble was experienced with stereotype metal due to coarse-grained, honeycombed plates. When technical control work was started, stereotype metal, after correction to the standard formula, was poured in air-cooled molds and cast into pigs weighing approximately 50 pounds each. As in the case of slug-casting metal similarly cooled, the metal was of a very coarse structure, and when remelted at the low temperature used for sterotype casting some segregation occurred, resulting in unsatisfactory plates. The method of cooling the metal was therefore changed and all stereotype metal issued for stereotype-plate casting was poured in water-cooled molds producing 25-pound pigs.

A 5-ton electrically heated stereotype pot equipped with a casting pump [8] was installed in the Platemaking

[8] This pot has since been replaced.

Division. Difficulty was experienced in the use of metal of the formula containing 8 percent tin, 15.5 percent antimony, and the remainder lead. It was found that the antimony, being in excess of the eutectic, had a marked tendency to separate from the alloy. Analysis made after the metal was allowed to stand overnight showed the metal in the upper part of the pot to contain between 30 and 40 percent antimony. The high antimony metal required a temperature in excess of 750° F. to melt it and also caused trouble by freezing in the pump. The plates were honeycombed, many of them being unfit for use.

It was decided to prepare and test a series of alloys containing varying percentages of tin and antimony in order to find an alloy which would give satisfactory results in the new electrically heated pot when cast at a temperature not exceeding 600° F. and one which would make satisfactory plates for the presses.

Composition of Stereotype Metals[1] *Tested*

Tin, percent	*Antimony, percent*	*Lead, percent*
6.5 to 7.0	13.0	Remainder
7.5	13.0	Do.
8.0	13.0	Do.
8.0	15.5	Do.
8.5	13.0	Do.
8.5	14.5	Do.
9.5	14.0	Do.

[1] Approximate copper content of these alloys, 0.1 to 0.2 percent.

These formulas represent metal of a high quality. Each alloy was used for periods varying from 2 to 18 days, depending on the quality of the plates produced. Two or three plates out of each run were cast in duplicate in order that plates used on the press could be compared with unused plates. Copies of the printed work were taken at the beginning and end of each run. Records were kept of the operating conditions in the casting room and also as to the performance of the plates on the press. Photographs were taken at a magnification of approximately 10 times, showing the type faces before and after runs on the presses. The plates photographed were chosen as being representative of all the plates cast from the metal of that particular composition.

As previously stated considerable trouble was experienced in casting with the new equipment when metal containing 8 percent tin and 15.5 percent antimony was used. The results obtained on the press were satisfactory. The antimony in the alloys containing more than 13 percent antimony was found to increase the melting point and showed a marked tendency to separate from the remainder of the metal. It was therefore decided that 13 percent antimony would be taken as our standard, provided the wearing quality of plates cast from this metal proved satisfactory.

Varying percentages of tin were tried with this percentage of antimony. It was found that the lowest casting temperature, 600° F., was obtained with an alloy containing 6.5 to 7 percent tin. Those containing higher percentages of tin require from 50° to 70° additional temperature.

Less difficulty was experienced in casting good plates from the metal containing 6.5 to 7 percent tin and 13 percent antimony than with the alloys containing higher percentages of tin. The plates were practically free from bubbles and blow holes, and having been cast at a lower temperature cooled faster. Also less trouble was experienced in the pressroom with these plates than those cast from the other alloys.

The alloys containing 8 to 9 percent tin in combination with 13 percent antimony required a higher casting temperature than that containing 6.5 to 7 percent tin and showed a tendency to yield porous plates. The porosity, however, may be attributed in part to imperfect alloying since the arrangement of the heating units in the electric pot made it difficult to obtain good agitation. Comparative tests of the 6.5 to 7 percent tin and 13 percent antimony metal and the old standard metal were made on flat work. Since the jobs were printed on bond paper considerable wear was shown within a short time. The photographs of the plates and also the printed work showed that the results obtained were practically identical.

The average number of impressions on the Congressional Record at that time was 35,000 (now 43,000). Plates made from all the formulas showed an appreciable amount of wear at the end of 35,000 impressions although they were still in good condition. A run of 70,700 was made on the Record press using metal containing 6.5 to 7 percent tin and 13 percent antimony.

Inspection of all the photographs of the plates and of the printed work indicated that the larger portion of the wear occurred prior to 35,000 impressions. It is evident, therefore, that the number of satisfactory impressions obtained from any stereotype plate is governed to a marked extent by the precision of both press construction and stereotyping equipment and the kind of paper being printed.

The alloy containing 6.5 to 7 percent tin, 13 percent antimony, and the remainder lead was finally chosen as giving the best results from the standpoint of casting and wear resistance on the press, and the formula containing 7 percent tin, 13 percent antimony, not more than 0.05 percent copper impurity, the remainder lead was adopted as the standard for stereotype metal for use in the Government Printing Office.

Stereotype plates duplicate the printing face of the original type form whether slug-cast or monotype composition. Either a wet- or a dry-matrix system may be used to mold from the original type face. The wet matrices used in this Office, now largely replaced by dry matrices, are made of several sheets of tissue and matrix paper separated by a thin film of paste containing clay, gum arabic, and flour. After molding, several casts or stereotype plates can be made from one matrix, and duplication is thus made rapid. This is especially useful to the newspaper publishers, whose desire is to print the largest number of papers in the shortest time after the copy is set in type. Dry matrices are also used by newspapers where the original type is not wanted after it has been molded and where the job is printed on newsprint paper.

Curved stereotype plates on cylinder presses using soft packing give 75,000 to 100,000 impressions, and if the stereotypes are nickel-plated, a much longer press run of 150,000 or more impressions may be secured. Stereotypes are cast by hand ladling, by automatic or semiautomatic pumps into air-cooled or water-cooled boxes, at a temperature of 515° to 600° F. In this Office, stereotypes are cast in vacuum casting boxes by hand ladling.

Type-metal crystal structure is affected by variations of the composition, by the casting temperature, and by the rate of cooling. A high casting temperature expands the molten metal. When such expanded molten metal comes in contact with the matrices or stereotype mats, the outside solidifies quickly, but the metal not in direct contact cools more slowly. This causes increased shrinkage and an open structure which impairs the strength of the plates.

ELECTROTYPE BACKING METAL

Investigational work was conducted to develop a standard formula for the composition of electrotype backing alloy and to standardize this metal in the same manner as has been done with slug-casting, monotype, and stereotype alloys.

Analyses of several samples of the alloy used in the Office indicated considerable variation in composition, the tin content varying from 7.8 to 9.8 percent, the antimony from 2.8 to 4.25 percent, and the copper from 0.05 to 0.15 percent, and the remainder lead.

Analyses of several samples of commercial alloys and data from metal supply companies showed that the metal in use by the Government Printing Office was much higher in tin than commercial alloys.

Since this metal was high in tin, it was not advisable to lower the tin content unless better or more economical results were to be obtained.

Investigation developed the fact that alloys containing different percentages of lead, tin, and antimony require varying lengths of time to reach their maximum hardness. Tests on metal containing approximately 9 percent tin and 3 percent antimony, and on other alloys containing 3 to 4 percent tin and 3 percent antimony, showed the former, containing the higher amount of tin, is practically at its maximum hardness within 2 hours after having been cast. Alloys containing the lesser amount of tin were much softer than the other metal for a considerable period of time. However, 48 hours after casting, the low-tin alloys became as hard as the one containing more tin.

The results were of considerable value in determining a standard composition for electrotype backing metal. A metal that is relatively soft during the finishing process and yet attains a hardness sufficient for satisfactory service on the press is more economical than a metal which attains its maximum hardness before the plates can be finished.

As a result of investigations, including analyses of commercial samples of electrotype backing metal and practical tests, a formula for electrotype backing alloy of 4 percent tin, 3 percent antimony, and the remainder lead was tentatively adopted. This formula has since been changed to 3.5 percent tin, 3.5 percent antimony, and the remainder lead.

Electrotype backing metal is not used as a printing surface but to give thickness and support to the copper or nickel electrotype shell, to which it is soldered by means of tinfoil and zinc chloride backing fluid.

Electrotypes, like stereotypes, are duplicates of the printing surface of the original type form, often with halftone or line-cut inserts.

The electrotype shell, after it has been backed up with electrotype backing metal, forms the printing surface of the electrotype plate. It usually consists of copper only but often is nickel faced with an under layer of copper. It is electrolytically deposited on a mold of wax, lead, thermoplastic resin such as Vinylite, or other material such at Tenaplate.

The type metal formulas used in this Office have been found satisfactory for the kinds and qualities of printing done here. It is recognized that special or other formulas may be required for use by others doing specialized printing work.

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