Mining and Metallurgical Section.

Stated Meeting, May 11, 1898.

THE MICROSTRUCTURE OF BEARING METALS.

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The science of microscopic metallography is at present attracting widespread attention, and great developments have of late resulted from this mode of testing. Microscopic examination is fast becoming a factor in testing metals. In the study of iron and steel much work has been done and much information obtained; but the microscopic examination of alloys is a comparatively new piece of research. Chemical analysis can show only the composition of an alloy; but to show the true structure, or manner in which the component parts are alloyed, is left for the microscope. The physical properties of a sound piece of steel depend exclusively upon its chemical composition and upon its structure, and just so with all other alloys; not only should the component parts thereof be known, but also the manner in which these metals are alloyed, as is shown by their structure. We may take, for instance, bearing metals. In these alloys two all-important points requisite to a good bearing alloy, namely, anti-friction and wearing qualities, are greatly dependent upon structure.

It is, of course, first necessary to have the composition correct to meet certain requirements, such as load, speed, etc., and then to have the component parts alloyed in such a manner that the product shall be as fine-grained and homogeneous as possible. The failure of many bearings to give satisfactory service is more often the result of improper mixing than of a poor composition.

It is an undisputed fact that certain combinations of metals are better than others, but it frequently happens that

an alloy of good composition is far inferior to another of poor composition, simply on account of improper manipulation; a good composition in the hands of unskilled foundrymen often yielding a granular and uneven mixture of very inferior quality, while a good metal can be made of inferior scrap by another.

How the wearing qualities are dependent upon structure will be made evident when we consider the definition of wear—"the tearing off of small particles from the worn bodies." Therefore, a bearing metal which is finer in granular structure will wear the slower because of the tearing off of smaller particles.

If a metal is not homogeneous, the anti-frictional qualities will suffer greatly, because of the difference in the hardness and density of the metal in all its parts. The particles of such an alloy form hard spots within the metal, which produce friction.

The homogeneity is greatly dependent upon the treatment the alloy has undergone, and a perfectly even structure can only be obtained by careful and proper treatment.

In view of these considerations, I was led to make a study of the structure as well as the composition of the various bearing metals on the market in this country, and more particularly those which are used in railroad service.

The question as to what is the best metal on which to run our rolling stock is one which is becoming more important every day. We are running our trains on faster schedule; we are increasing the size and weight of locomotives and cars to acquire greater speed, greater carrying capacity and greater comfort.

Only a comparatively few years ago railroad men would have laughed at the idea of attaining the train weights and speeds of to-day. They would have advanced a hundred difficulties in the way of achieving such wonderful results, and chief among these would have been cited the difficulty of obtaining a bearing metal which would meet these requirements. In former times, when speed was not attained and comfort but little considered, a "hot box" was of little consequence; but now the numerous trains are required to

dash along with marvellous regularity, reaching their destination after a run of hundreds of miles on the very minute they are scheduled to arrive. Under these conditions even the slightest delay often leads to the most disastrous consequences. Many accidents are on record which can be traced to a hot box.

Apart from the safety and successful movement of trains which can be accomplished only by the use of well-fitted, well-lubricated bearings, composed of a properly made anti-friction alloy, the question of cost is also an important factor—not only first cost, but also the expense which is directly dependent upon the wearing qualities of the alloy and its successful use as scrap. A metal to be successfully used as scrap must have the quality of not deteriorating in remelting. The importance of these considerations is at once obvious to a well-regulated railroad, which considers the great loss occasioned by wear, and the necessity of converting their scrap again into a first-class journal brass.

The alloys now in use for this purpose may be divided into five classes :

- (1) White metal alloys.
- (2) Miscellaneous alloys.
- (3) Copper and tin alloys.
- (4) Phosphor-bronze.
- (5) Copper, tin and lead alloys.

Cast iron has been tried as a journal metal on railroads, and in fact was used for some years, but I think that it has now been entirely abandoned for the composition metals. Roller bearings have also been experimented with, but, so far as I am aware, have failed to give satisfaction.

The preparation of these alloys for microscopic examination is, of course, of first importance. They must be carefully polished and then etched with a suitable reagent. For copper alloys I prefer to use method of Guillemin, *i. e.*, to attack the specimen electrolytically by exposing it for a few minutes in a bath of very dilute sulphuric acid when connected with a simple Daniel cell, and, in making a comparative study of metals of similar composition, all the conditions must be the same. The method I use is to make a

platinum dish, containing the weak acid solution, the positive pole, and then immerse the specimens to be compared in the solution in contact with the dish, and pass a current through them all at the same time.

The white metal alloys belong to the first class. They are first in anti-frictional qualities, but do not wear well, and furthermore have not sufficient strength to support the great weight of locomotives and cars without distortion or crushing. The practice, therefore, is to use these metals inside of a stronger shell of composition metal.

In car bearings these soft alloys are simply used as a lining, which is not more than $\frac{1}{16}$ to $\frac{1}{8}$ of an inch in thickness. The object of this lining is to give the bearings a good seat without having to be bored out accurately to fit the diameter of each individual axle. The diameters of the axles vary according to the wear they have had, and to fit hard-metal bearings it would be necessary to bore each one to fit each particular axle, and moreover the axles are always more or less rough. The soft white metals easily conform to any such irregularities in the surface of the axle.

This soft composition soon wears away, but by the time this has taken place the bearing has a good seat on the axle, thus doing away with the necessity of fitting each separate journal. The boxes are all bored out to the same diameters and lined with a specified thickness of soft metal. In this way the bearings are all fitted with the minimum expense and confusion. The principal alloy used is one containing antimony and lead; this is sold on the market under the name of "hard lead." It usually contains from 15 to 25 per cent. of antimony, which makes the alloy coarsely crystalline and brittle. It is inexpensive, but gives little wear. Although antimony is a more expensive metal than lead, the "hard lead," or antimonial lead, sells at a lower price than pure lead. The microstructure shows these coarse crystals (*Fig. 1*). With the increase of antimony the crystals are brought into closer contact, indicating the approach to the chemical alloy. Tin greatly improves this alloy. It gives it greater toughness, and makes an alloy which will stand a much greater pressure without distortion, a valuable feature for a babbitt metal.

This is the composition of nearly all the cheap babbitt metals on the market. A good babbitt metal should have as fine a grain as possible in connection with the greatest toughness and hardness obtainable. Tin has the property of greatly reducing the granular texture of antimonial lead. Bismuth in small quantity is added to the lead, antimony and tin alloy by some manufacturers. It is claimed to give greater fluidity and less distortion under pressure. The composition of such an alloy is:

Lead	80'00
Tin	4'75
Antimony	15'00
Bismuth	'25

The question of obtaining a fine-grained structure depends greatly on the method of manufacture, temperature of pouring playing an important part, but generally the size of the crystals increase with the increase of antimony, as does hardness; but by proper manipulation a finely crystalline metal can be obtained in an alloy of the following composition, which has a high percentage of antimony, thus making it a valuable babbitt metal:

Lead	70'00
Antimony	20'00
Tin	10'00

The first white metal successfully used as a bearing metal was invented by Isaac Babbitt. It contained tin, antimony and copper. This metal is used for lining purposes, but can be cast into solid bearings which do not carry too great a load. All white metals used for bearing purposes are now sold under the name of babbitt metal, and when used as a lining the bearing is said to be "babbitted." But to distinguish this metal from the cheaper lead alloys it is sold under the name of "Genuine Babbitt." This alloy is harder than the lead alloys, much tougher, and is finely crystalline and wears well. It is much more expensive, owing to the content of tin. The composition is as follows:

Tin	80'00
Copper	10'00
Antimony	10'00

Another alloy very successfully used is one composed of:

Tin	68.00
Zinc	31.50
Copper	1.00
Lead	.50

It is very tough and bends many times without breaking, due to the peculiar interlocking of the crystals (*Fig. 2*). It has, however, the bad feature of pouring sluggishly. I have no knowledge of the wearing qualities of this metal.

I will next consider the miscellaneous alloys. Under this head may be included any alloy, it matters not what the composition, so long as it produces a reasonably good casting. It includes all alloys having over 60 per cent. of copper and the remainder made up indiscriminately of zinc, tin, lead, antimony and any other metals which happen to be in the scrap pile.

Such compositions as these are used on freight cars, and, indeed, by some roads in passenger service, their only aim being to get a cheap composition. No attention is paid to wearing or other qualities, and the running expense is not taken into account; it is only first cost. If a bearing gets hot or wears out, it is removed and thrown into the scrap pile, to be again remelted. Foundrymen receiving this scrap term it all "red brass," and without any knowledge of the composition, again convert it into journal bearings.

The scrap pile always contains more or less zinc, and indeed anything from yellow brass up is considered good enough for a cheap bearing metal,

Fig. 3 shows the structure of yellow brass of:

Copper	66¾ parts
Zinc	33¼ "

It is beautifully crystalline and the size of the crystals varies greatly with the method of treatment. Zinc has the property of giving greater solidity to alloys of copper, tin and lead, 1 to 2 per cent. being sufficient for this purpose, and when more than this is used in connection with other scrap the effect is more or less injurious. If the scrap metal coming from the railroads was first melted and run into pigs

and analyzed, uniform results could be obtained by building up the scrap with new metal to the desired composition; but the present low price of such material would not warrant this extra expense; and, indeed, I have known of such bearings to be cast, bored out and lead-lined for $7\frac{1}{2}$ cents per pound. But even so, with proper care, a fairly good metal can be made from such scrap.

Fig. 4 shows a bearing metal made of scrap which has been carefully treated; it contains a high percentage of lead, but shows no liquation of the lead as would be expected in an alloy of this nature.

Fig. 5 shows a copper and tin alloy, containing a little lead, in which manganese has been used as a deoxidizer.

The alloy of copper and tin some years past was considered the standard bearing metal on railroads, but is now little used. These metals alloy to form a very hard and crystalline alloy, *Fig. 6*, the usual proportion being that of cannon bronze—7 parts of copper to 1 part of tin. Although this alloy is much harder than the standard metals of to-day, yet it is found to wear much more rapidly and produce more friction. Dr. Dudley, chemist to the Pennsylvania Railroad, some years ago gave the results of a long series of experiments before the Franklin Institute, in which he compared the copper and tin alloy with standard phosphor-bronze, which contains lead. He found that the copper and tin alloy was much more liable to heat under the same state of lubrication than the standard phosphor-bronze, and second, that the rate of wear with the copper and tin alloy was nearly 50 per cent. greater than that of the standard phosphor-bronze. And still, in spite of these facts, some railroads still go on in the old way specifying copper and tin, a more expensive alloy than the phosphor-bronze, or the copper, tin and lead composition.

These experiments led directly to the use of standard phosphor-bronze bearing metal on the Pennsylvania Railroad, and indirectly to its use on other large roads. Thus, by practical experimentation and experience, railroad men to-day recognize but two alloys as standard: (1) Copper, tin and lead alloy, containing phosphorus, known as phosphor-

FIG. 1.—Antimonial lead.

FIG. 2.—Tin and zinc with little copper and lead.

FIG. 3.—Copper and zinc.

FIG. 4.—Copper, zinc, tin, lead, iron.

FIG. 5.—Copper and zinc with little lead (manganese used as deoxidizer).

FIG. 6.—Copper and tin.

FIG. 7.—Copper, tin, lead and phosphorus (1st melting).

FIG. 8.—Copper, tin, lead and phosphorus (after repeated meltings).

FIG. 9.—Copper, tin and lead (1st melting).

FIG. 10.—Copper, tin and lead (after repeated meltings).

FIG. 11.—Copper, tin and lead, showing liquation of lead.

FIG. 12.—Copper, tin and lead, showing liquation of lead.

bronze. (2) Copper, tin and lead. I do not say that either of these alloys is the best that can be devised, but up to the present time, and with our present knowledge, they are the best compositions for car and locomotive journal bearings. As far as wearing is concerned, I do not think the phosphorus introduces any advantage, and, as Dr. Dudley says, he has no evidence to show that the phosphorus has any other use except to produce sound castings.

I had occasion very recently to find, by a practical test, that the alloy of copper, tin and lead gave better results, so far as anti-frictional qualities are concerned, than the alloy containing phosphorus. That the bearings without phosphorus showed a much less tendency to heat than the phosphor-bronze was clearly demonstrated. The test was made by placing the phosphor-bronze on one side of the axle and the simple alloy on the other. The tests were strictly comparative in every way, and the number of hot boxes of the phosphor-bronze metal greatly exceeded the simple alloy. And it has been found, by practical experience, that remelted phosphor-bronze is much more liable to heat than the newly-made metal.

In order to discover why the remelted scrap phosphor-bronze should be inferior to the newly-made material, I determined to make some experiments in a practical way. The fact that the phosphor-bronze scrap is far inferior to new metal is well known, and I believe the general impression has been that the inferiority was due to the burning out of the phosphorus, as it is for this reason that the specifications of standard phosphor-bronze call for a high percentage of phosphorus, in order to make provision for loss in remelting, and with the idea that the remelted scrap will still retain sufficient phosphorus not to deteriorate its qualities. By my experiments I find this to be an entirely mistaken idea, because, in the first place, phosphorus only burns off in very small proportions, when once thoroughly contained in the alloy; and secondly, that the inferiority of the metal is directly due to the high percentage of phosphorus, for the reason that it combines with the tin and copper to form hard crystalline phosphides, which are, to a

great extent, dissolved in the alloy when the metal is new, but separate or crystallize out in the old material.

Six hundred pounds of phosphor-bronze was made of good selected material, and every precaution used in manipulating. It was then poured into ingots and borings taken from the first, middle and last ingots, and the borings mixed and analyzed. The analysis showed:

Copper	78.72
Lead	9.89
Tin	10.58
Phosphorus	1.04

Three hundred pounds of these ingots was now weighed off and remelted, and again poured into ingots and weighed, and the loss carefully noted; the metal being melted and poured in this way ten times, and the loss noted in each heat with the following results:

	<i>Pounds.</i>		<i>Pounds.</i>
1st	3.5	6th	2
2d	3.0	7th	3
3d	3.0	8th	3
4th	2.5	9th	4
5th	3.5	10th	7

The total loss was 34.5 pounds, or 11.5 per cent. on ten heats, and the average loss per heat 1.5 per cent. It will also be seen how uniform was the loss on every heat; the last heat only showing considerable deviation, which I attribute to the metal being insufficiently hot to flow cleanly from the crucible.

Borings were taken from the first, middle and last ingots of the tenth heat, well mixed and analyzed. The metal now contained its constituents in the following proportions:

Copper	80.39
Tin	10.40
Lead	8.35
Phosphorus	.87

The analysis shows that very little phosphorus has gone off, despite the fact that the metal was melted and poured ten times, the lead showing the greatest loss. The following table will show the loss in weight very closely, as shown by the analysis:

	<i>1st Heat.</i>	<i>10th Heat.</i>	<i>Loss in Pounds.</i>
Copper	235'47	213'41	22'06
Tin	29'67	27'61	2'06
Lead	31'74	22'17	9'57
Phosphorus	3'12	2'31	'81

These results show that the phosphorus is held in bronze in the form of phosphides, which high temperature can drive out only in very small proportions. The metal under the microscope was now decidedly crystalline. These crystals are intermixed or held dissolved in the new metal, but when subjected to remelting become organized and crystallize out in the alloy, thus greatly reducing the anti-frictional and wearing qualities of the metal. The resulting metal after the tenth heat was so hard it could scarcely be touched with a file. { *Fig. 7.*—New phosphor-bronze.
Fig. 8.—Remelted phosphor-bronze.

A copper, tin and lead alloy of the same composition was treated in the same way; the loss on this metal was 34 pounds, being within half a pound of the phosphor-bronze, and the loss on each heat was as follows :

	<i>Pounds.</i>		<i>Pounds.</i>
1st	7	6th	4
2d	3	7th	2
3d	1	8th	3
4th	4	9th	3
5th	4	10th	3

This metal became harder and closer-grained after the repeated meltings, but showed no signs of becoming crystalline or granular.

Fig. 9.—New copper, tin and lead alloy.

Fig. 10.—Remelted copper, tin and lead alloy, made by the Ajax Metal Company's process, which insures the homogeneous distribution of the lead.

Many alloys of copper, tin and lead are manufactured by foundrymen under the name of anti-frictional metal and are sold under various well-sounding names, which are supposed to indicate their qualities.

To one who is unacquainted with or does not consider the chemical and physical properties of lead, it appears an easy matter to make such an alloy by merely melting in a

crucible the three metals in the stipulated proportions; but when we consider the greater density, the lower melting point, and the slight affinity of lead for the copper and tin alloy, a more serious question results. I have found, by my repeated microscopic examinations of many such alloys of different makers, that lead is in no instance combined or really alloyed with the copper and tin, or perhaps only in small proportions, probably not over one per cent.; the remaining lead being held diffused through the alloy in its combined state, or with small proportion of the tin and copper, but not enough to destroy the grayish-blue color.

Such an alloy under the microscope is seen to be made up of two principal colors, the bronze-colored combined copper and tin, and the grayish-blue lead. Now, this being the case, it will be seen how difficult and also important it is to obtain an alloy which will show the same structure and percentage of lead in all its parts. The difficulty in obtaining such an alloy is this, as I have stated:

(1) The lead is not combined with copper and tin.

(2) Owing to the high specific gravity and the lower melting point of the lead, its tendency is to go to that part of the casting which has last solidified, or to distribute itself unevenly throughout the mass.

I will now show the structure of copper, tin and lead alloys of several makers; they all have about the same composition and were all cast in the same size bars, great care being taken to have the conditions as nearly alike as possible. A section was cut out of the middle of each bar for examination.

Fig. 11 shows the structure of an alloy of the following composition:

Copper	76.88
Tin	10.62
Lead	11.71

It shows that the lead has liquated, leaving an unsound metal. The dark spots are holes and the lighter particles lead. That such a segregation of the lead greatly reduces the value of a composition of this nature is very evident.

Fig. 12.—A metal of following composition:

Copper	76.66
Tin	11.68
Lead	10.83

This shows a still greater segregation of lead. In this metal the lead is very unevenly distributed, it having formed large pools through the alloy.

Of all metals, lead is by far the first in anti-friction qualities; and if to the strength of copper and tin there is added a suitable proportion of lead, thoroughly and evenly distributed throughout the mass, the bearings as they wear are constantly in contact with soft anti-friction particles of lead, which are backed by the harder particles of copper and tin. If in such an alloy the lead is not homogeneously distributed and without liquation, both the wearing and anti-frictional qualities are greatly affected.

After going through the whole subject of the composition of metals suitable for bearings, the thoroughly homogeneous alloy of the proper proportions of copper, tin and lead seems to me to be the best suited for the purpose, and this has also been demonstrated in actual service by the use of such an alloy on all the record-breaking trains of recent years, notably the New York Central & Hudson River Flyer from Albany to Buffalo, which made the run of 436½ miles in 407 minutes, with the bearings perfectly cool throughout the entire run; and on the fleetest ocean greyhounds that cross the ocean.

The alloy of copper, tin and lead, of proper composition and homogeneous structure, I think I am safe in saying, has greater anti-frictional qualities than any other composition of sufficient strength to be used as a journal brass in railroad service. This fact has been demonstrated several times by actual practical tests, and furthermore, it does not deteriorate in remelting.

As structure is of such importance in a bearing metal, I think the micro-test should be included in all specifications as equal, if not greater in importance than chemical analysis.

DISCUSSION.

MR. JAMES DE BENNEVILLE.—Mr. Clamer's paper with the microsections he has exhibited throws additional and

valuable light on the structure of alloys which recent investigation is beginning to connect so closely with the action of solvents and dissolved substances. To refer more particularly to iron carbides, the microstructure of these bearing metals and of steel can be read together in the same light only up to a certain point. In comparing the two, the structure of the eutectic is an important determination. These mixtures have been shown, by the interesting work of Mr. Charpy, to possess a laminar structure, and are described by him as of the same nature as cryohydrates, the heterogeneity of which has been thoroughly established by Offer. Granted such heterogeneity, presence or absence of structure has a most important bearing on the structure of steel and kindred iron carbides. Mr. Charpy has pointed out that in the pearlyte structure of annealed steel all the conditions of a eutectic are found. Now, if we turn to the much-discussed .90 carbon steel quenched above A_1 (martensite), this is not found to be the case. Micrographists are substantially agreed that no structure can be detected in such steel. It is homogeneous. Two explanations have been put forward to explain this case: (1) that the carbon is dissolved in the iron and all compounds have disappeared, the relation of carbon to iron being analogous to that of sugar in water; and (2) that a definite compound of iron and carbon has been formed, viz.: $Fe_{24}C$. Difficulties arise in applying either of these explanations. If at high temperatures carbon is simply dissolved in iron, and is so retained on rapid cooling, thus forming a solid solution, the chemical relation known to exist between iron and carbon, and giving rise to cementite (Fe_3C) must be put aside, but it is to be noted that although carbon can be dissolved by iron, only carbide of iron can be again separated on slow cooling, unless a certain percentage of carbon is exceeded. If, however, the presence of cementite is admitted, the unusual example is presented of complete dissociation of the compound $Fe_{24}C$ in somewhat concentrated solution, whereas it has been found that in the case of electrolytes the more advanced the dissociation the greater is the dilution required. For

carbon, martensite covers the range up to .90 per cent. In quenched low carbon steel of .20 carbon, microanalysis shows two constituents, ferrite and martensite. If martensite is a definite compound, the explanation Fe_{24}C is accepted. If it is structureless in .90 carbon quenched steel, there is surely no reason to assume structure in .14 carbon quenched steel. To reject definite composition is to grant that martensite of .90 carbon steel is not identical with martensite of .14 carbon steel. If martensite varies in composition with the composition of the steel in which it is found, one distinguishing feature of a eutectic is at once lost, viz.: constancy in its physical properties; for this very constancy first gave rise to the idea that these mixtures, having constant boiling points, freezing points, etc., were definite chemical compounds. It is the definition of a eutectic.

As cast iron and vitreous silicates showed analogies in their conduct toward reagents, the writer (1894) was led to associate these "mother liquors" of iron carbides with such vitreous silicates. If martensite is regarded as analogous to such a compound, many difficulties are removed, and its varying composition, ultimate and proximate, can be understood. Can the indefinite structure of the vitreous silicates be regarded as necessarily implying a solution holding ions of calcium, magnesium, silicon and other elements? The definite ratios found to exist in the silicates, and which allows their range and the replacing value of each element to be predicted, does not uphold this view. The vitreous silicates can indeed be regarded as a solvent for certain compounds (feldspar, etc.), in the sense that water is a solvent. It does not imply anything more. Moreover, it is to be remembered that solution does not necessarily imply ionization, of which instances can be cited in the small value of μ for complex organic acids, and also when solvents other than water are used. The homogeneity of .90 carbon steel, hardened by quenching from $1,000^{\circ}$ —martensite—presents peculiarities not yet detected in the structure of the alloys described by Mr. Clamer and others.

THE PRESIDENT OF THE SECTION.—The phenomenon known as "segregation" of alloys, which has been alluded to

by Mr. Clamer in his interesting paper on the microstructure of bearing metals, is a remarkable one, apparently forming an exception to ordinary chemical laws.

It is an important subject for investigation by metallurgists and chemists, and if the microscope can cast new light upon the strange behavior of such alloys it will add much to the practical utility of this instrument in the laboratory.

Segregation is often used as a convenient cloak to cover faults of melting; but apart from this, it is indeed a serious trouble to the melter who aims to obtain homogeneous alloys.

The most thorough investigation of segregation with which I am familiar was made in the assay department of the mint, a good many years ago, with various alloys of the precious metals used in coinage. It was proved that when gold and copper were melted together in the proportion required for the American coin, *i. e.*, 900 parts of gold and 100 parts of copper, and the molten metal poured into ingots, after having been thoroughly rabbled with a plumbago stirrer, a homogeneous alloy resulted; test pieces cut from different ingots all assayed alike, within a minute fraction—not more than one or two ten-thousandths variation above or below the standard. When, however, an alloy of 900 parts of silver and 100 parts of copper was poured into ingots, after having been thoroughly mixed, considerable irregularity was found to exist in the distribution of silver in different ingots, and even in different parts of one ingot, and this variation was proved to be solely owing to segregation into richer and poorer alloys; furthermore, it was discovered that there was a specific alloy of silver and copper of certain proportions—I believe about 750 parts of silver and 250 parts of copper—in which segregation was almost *nil*.

In some of the silver-copper alloys the silver segregates towards the center of the mass, leaving copper in excess near the exterior portion. In other similar alloys a reverse effect was observed, and this is, of course, independent of the specific gravity of the metals.

The coinage silver laws of the United States permit a

comparatively large variation (called the "legal tolerance"), from the standard equivalent to $\frac{3}{1000}$ above or below 900 fine, on this account; but segregation may actually cause a variation in the fineness of two silver dollars struck from one ingot, or even in the metal clipped from different parts of a single dollar, sufficient to condemn the coin if judged from these assays alone; in order, therefore, to obtain an average sample of a melt of standard silver-alloy for coin, it is the universal practice in minting operations to dip out from the melting pot (containing usually 3,000 ounces of fluid metal) a small sample immediately after thorough stirring, and to quickly pour it into cold water; the alloy is thus instantly congealed into the form of shot or "granulations" and segregation does not occur under these conditions. Assays are then made of these granulations, and duplicate analyses must agree within very small limits of permissible variation.

About twenty years ago I made some few investigations with the microscope of silver-copper alloys with the view of trying to ascertain the cause of segregation, but met with little encouragement, and I am interested, therefore, to know whether Mr. Clamer has succeeded in solving this riddle through his more thorough study of the microstructure of bearing metal alloys.

NOTES AND COMMENTS.

TRIPLER'S APPARATUS FOR THE COMMERCIAL MANUFACTURE OF LIQUID AIR.

Engineering News of recent date contains the first intelligible account that has yet appeared concerning the construction and operation of the apparatus by which Mr. Chas. E. Tripler, of New York, has succeeded in successfully solving the problem of producing liquid air as an article of commerce. The following description is gleaned substantially from that which is published in the *News*, and which purports to be based on actual observation by a member of its staff:

From this account it appears that the apparatus, aside from a special portion of the mechanism, called by the inventor a "liquefier," is an ordinary compressed air plant.

The power is obtained from a steam boiler which supplies steam at about 85 pounds pressure to a Norwalk straight-line compressor rated at 90 horse-