SEGREGATION AND GROWTH OF CRYSTALS IN BEARING METALS.

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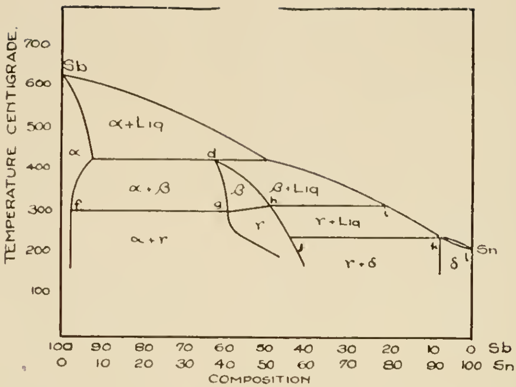
Bearing metals that have been used successfully in industrial practice are alloys that crystallize as conglomerates upon cooling from the liquid condition. A commonly accepted theory accounts for the anti-frictional qualities of such alloys upon this basis. It is understood that there must be certain hard particles embedded in a softer and more yielding matrix. The hard components serve to resist abrasion and to endure the wear and they are enabled to assume a form to accommodate microscopic irregularities of the moving journal surface through the limited plasticity of the supporting metal.

This being true, the conclusion seems obvious that it is highly important that a good bearing metal should be so constituted that the hard crystals are relatively small and well distributed but this is a most difficult condition to obtain in practical bearing casting. The formation of various metallographic constituents occurs at different temperatures and continued heating of the alloy results in rapid growth of any crystals that may have formed at that temperature or at a higher temperature. Also it is generally true that either flotation or settling occurs in the semi-liquid mass during cooling, since there are often considerable differences between the specific gravities of the solid and liquid portions. Growth and segregation may thus result in the formation of a bearing of very poor anti-frictional properties, even though the composition of the alloy as a whole is correct.

The work described in this paper has to do with one phase of an investigation of the relations existing between melting and pouring conditions on the one hand, and crystal segregation and growth on the other, of the alloy of tin, copper and antimony known as Babbitt metal or Navy Babbitt metal. The alloy used in the experimental work had the composition: tin 85.70%, antimony 9.86%, copper 3.34%, zinc 0.70% and lead 0.40%. The last two metals are to be regarded as impurities rather than as essential constituents.

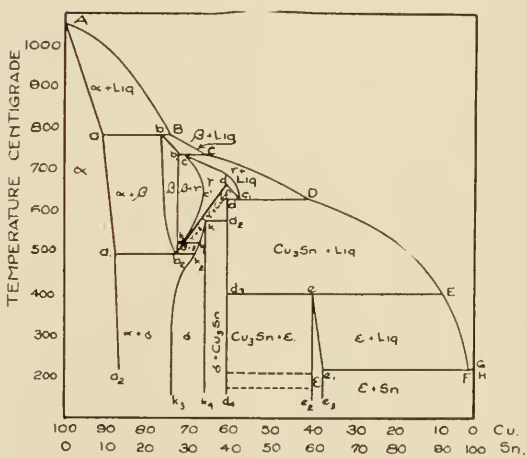
The constitutional diagrams for the binary tin-antimony and tin-copper systems, respectively, are shown in Figs. 1 and 2. These represent the conclusions of a number of experimenters and the diagrams are reproduced from Gulliver's "Metallic Alloys". The constitutional diagram for the ternary system tin-antimony-copper is not so well worked out but a part of the diagram, more or less idealized, is shown in Fig. 3. Referring to the composition of Babbitt metal, given above, it will be seen that the only metallographic constituents that will have any considerable importance in this connection are ϵ-tin-copper and γ-tin-antimony crystals. In the the photomicrographs the latter are shown as cubes, the former as peculiarly shaped crystals arranged in straight chains, stars and triangles.

γ-tin-antimony is the hardest constituent of this alloy and it also has the lowest specific gravity. It forms on the branch i-k of the liquidus of



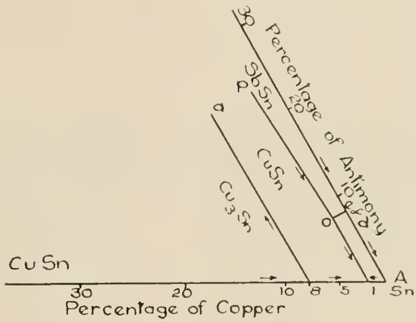
Equilibrium Diagram for Antimony Tin Alloy

Fig. 1



Equilibrium Diagram for Copper -Tin Alloys.

Fig. 2



Part of Provisional Copper-Antimony-Tin Diagram.

Fig. 3

Fig. 1. ϵ-tin-copper also is hard, has a lower specific gravity than that of tin and forms first of all crystals of the alloy of this composition, on a falling temperature, along the branch E-F of the liquidus of Fig. 2.

These crystals grow rapidly at temperatures within their formation ranges. On account of their relatively low specific gravities flotation in the still liquid portions readily occurs. It may easily happen that a given bearing may have its hard, wear-resisting components so large that they become broken in use and so distributed as to possess quite different properties at different points. Figs. 4, 5, 6, 7 and 8 illustrate the rapidity of flotation.* Metal was melted and immediately poured on a warm iron plate. A sheet about one-fourth inch in thickness solidified in less than thirty seconds. Figs. 4, 5, 6 and 7 show the cast, unpolished upper surface, Fig. 8 the lower surface, polished and etched with nitric acid. Even in the short time that elapsed between pouring and solidification, segregation of -crystals has occurred to so great an extent that none at all are present in the lower surface layer. Figs. 9 and 10 illustrate the extent of growth under unusual conditions, although it may be noted that such conditions might easily be brought about by inadequate control of furnace conditions.

Rapid growth and segregation at higher temperatures are well recognized phenomena. In the experiments described in this paper an attempt was made to determine the relative rates of growth and segregation of the two systems of crystals here mentioned, in temperature ranges near the respective solidi.

Working specimens were first prepared by melting a quantity of the alloy at 650° C., stirring thoroughly with a stick of wood and immediately casting in chill molds of cast iron. This resulted in the formation of fine crystals, as shown in Figs. 11 and 12, taken after polishing and etching sections of two of the pieces. These specimens were then heated to stated temperatures and either chilled or slowly cooled after certain periods of time. Treatments at temperatures above 250° C. were carried out by heating in covered crucibles in an electric muffle furnace. For lower temperatures the specimens were immersed in a bath of heated glycerine.

Sections of the treated specimens were examined and photographed as before. A measurement of crystals was made on the ground glass of the camera and actual sizes calculated. In the chill cast specimens γ-tin-antimony crystals varied from 0.015 to 0.05 mm and ϵ-tin-copper from 0.02 to 0.18 mm in their ,longest dimensions. In table I are summarized the results of the various thermal treaments of the chilled pieces. Figs. 13 and 14 illustrate two of the treatments in the lower temperature ranges.

*All photomicrographs have been reduced one-third by the printer.

TABLE I

Temperature to which reheated, degrees C.	Time, hours	Size of tin-antimony crystals, millimeters		Sizd of tin-copper crystals, millimeters	
		Upper section	Lower section	Upper section	Lower section
550	4	0.28 – 0.55	0.25 – 0.50	0.10 – 2.50	0.10 – 2.50
550	4	0.36 – 0.56	0.34 – 0.50	0.15 – 2.50	0.12 – 2.00
550	1	0.30 – 0.55	0.20 – 0.45	0.10 – 1.40	0.10 – 2.00
550	1	0.24 – 0.48	0.20 – 0.46	0.06 – 1.20	badly broken
550	1	0.28 – 0.55	0.20 – 0.46	0.10 – 1.60	0.10 – 1.30
475	4	0.30 – 0.62	0.20 – 0.48	0.04 – 0.40	0.04 – 0.40
475	4	0.22 – 0.67	0.20 – 0.45	0.10 – 1.20	0.10 – 1.00
300	1	0.20 – 0.40	0.12 – 0.30	0.03 – 0.60	0.02 – 0.22
300	1	0.09 – 0.26	0.08 – 0.22	0.03 – 0.41	0.03 – 0.36
240	2	0.06 – 0.18	0.03 – 0.12	0.04 – 0.21	0.03 – 0.18
230	1½	0.03 – 0.13	0.03 – 0.09	0.03 – 0.18	0.03 – 0.18
225	3	0.05 – 0.14	0.04 – 0.10	0.04 – 0.23	0.03 – 0.20
220	4	0.025 – 0.04	......	0.02 – 0.15	......
210	4	0.03 – 0.05	......	0.015 – 0.125	......
200	6	0.03 – 0.05	......	0.02 – 0.13	......
180	6	0.03 – 0.05		0.02 – 0.12	......
160	4	0.03 – 0.05	0.015 – 0.035	0.02 – 0.17	0.02 – 0.10

Fig. 4.—Metal melted at 550° and poured on a warm iron plate. Upper surface. X 50

Fig. 5.—Same conditions as in Fig. 4. Upper surface. x 50

Fig. 6.—Same conditions as in Fig. 4. Upper surface. x 50

Fig. 7.—Same conditions as in Fig. 4. Upper surface. x 50

Fig. 8.—Same conditions as in Fig. 4. Lower surface, polished and etched. x 50

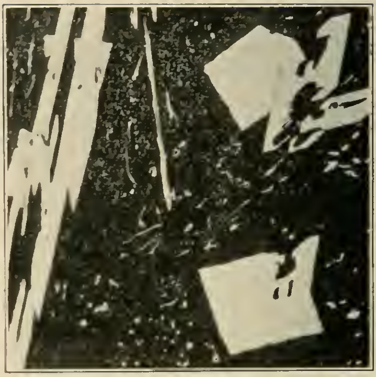


Fig. 9.—Heated to 800° C. for 1 hour, cooled in furnace. x 50

Fig. 10.—Heated to 800° C. for 1 hour, cooled in the furnace. x 50

Fig. 11.—Melted at 550° C. and cast in iron chilled mold. Vertical section. x 50

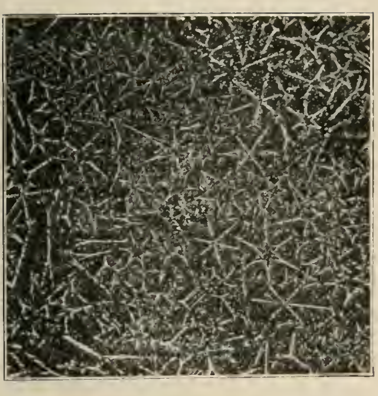


Fig. 12.—Melted at 550° C., cast in iron chilled mold. Horizontal lower section. x 50

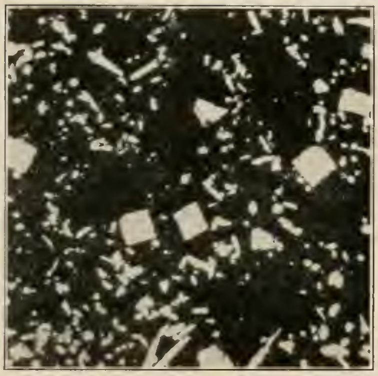


Fig. 13.—Chilled piece of Figs. 11 and 12 reheated at 230° C. for 1 hour. x 100

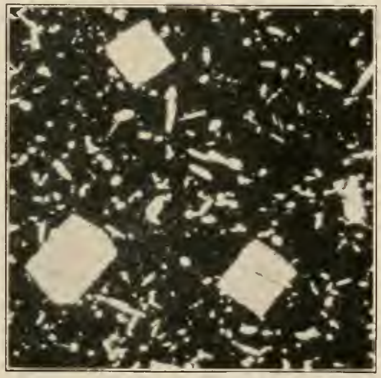


Fig. 14.—Chilled piece of Figs. 11 and 12 reheated to 240° C. for 2 hours. x 100

An inspection of the table and photomicrographs shows that appreciable growth and segregation take place even at temperatures as low as 225°, this temperature being practically at the lower boundary of the area of formation of ϵ-tin-copper and near the lower boundary of the γ-tin-antimony range. As this temperature is well below the liquidi for both binary systems involved in the alloy here used it will readily be seen that practical melting and casting of bearings of Babbitt metal is necessarily done at considerably higher temperatures, thus offering correspondingly greater opportunity for crystal growth and segregation. It may be remarked that Gallagher found* a very slight crystal growth after several weeks heating at 218° C., a temperature below the solidi for both binary systems.

*J. Phys. Chem., **10**, 93 (1906).