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CONSERVATION OF TIN IN BEARING METALS, BRONZES, AND SOLDERS

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I. INTRODUCTION

From a metallurgical standpoint there are several ways in which a reduction of the tin consumed in commercial nonferrous and white-metal alloys can be effected: First, a reduction of the tin content of the alloy; second, substitution of part or all of the tin content by some other metal; and third, a substitution of a different type of alloy, which in some cases also involves a change in mechanical design. The Bureau of Standards has been studying these methods of conservation for tin alloys, particularly in regard to babbitts and bearing metals, bronzes, and solders.

Much of the information secured by the Bureau was obtained from answers to questionnaires sent to manufacturers and users of these materials, such that, in general, any suggestions or recommendations made can be considered as being practical and as having already been thoroughly tried.

II. BEARING METALS

There is no question but that the tin content of nearly all bearing metals can be reduced to some extent, and in some cases actually eliminated, without prejudice to the service rendered.

So the problem is to determine what needs are the most exacting or when a breakdown would cause the greatest damage and confine the use of high tin babbitts to these uses only. Thus the main bearings of airplane and military automobile engines, turbine shafts, etc., will probably have to continue to use high tin babbitt with a tin content of from 84 to 91 per cent. A babbitt metal such as S. A. E. specification No. 24 containing 84 per cent of tin, 9 of antimony, and 7 of copper appears to be as satisfactory in service as genuine babbitt—89 per cent of tin, 7½ of antimony, and 3½ of copper—or that specified by the International Aircraft Standards Board—91 per cent of tin, 4½ of antimony, and 4½ of copper; but it should be pointed out that the latter two compositions are more fluid in the molten condition than the first named and consequently the lining can be made in a thinner shell with these babbitts, and the total amount of tin consumed may therefore be less than if the S. A. E. No. 24 were used. However, if the design of the bearing is not altered to admit of the thinner shell, the lower composition babbitt should be used in general.

The following compositions are also recommended for use where a high grade of lining is required and where a genuine babbitt is often now used:

Ingredients	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Tin	65	62	8	5	10	21.3
Antimony	.....	.....	8	7	12.5	.....
Copper	3–6	4	4	2	.5	3.0
Zinc	28–30	23	.....	76	.....	63.3
Aluminum	.....	1	.....	.....	.....	.....
Lead	.....	.....	80	10	77	12

Nos. 3 and 4 have been found to do the service required of tin base linings in machine-tool bearings. No. 5 can be used on similar bearings where a greater strain is met. No. 6 is in use in Germany as a "best" babbitt to conserve both tin and copper.

For linings on railroad-truck journals two compositions are in general use, one composed of 85 per cent of lead, 10 of antimony, 5 of tin, and the other of 87 per cent of lead and 13 of antimony. The latter is restricted by some roads to freight service and the former used on passenger equipment. Many roads, however, use the 87 per cent of lead and 13 of antimony on both classes of service, and it seems that its use might be made more universal.

Another type of lining metal which deserves serious consideration is one composed almost entirely of lead, with small additions

of alkali or alkali earth metal. Certain of these have been given service tests at the Bureau of Standards and in many respects were found equal to or superior to genuine babbitt.

Following is a summary of the tests on the metal and similar tests on genuine babbitt of composition 89 per cent of tin, 7½ of antimony, and 3½ of copper.

GENUINE BABBITT

Load, pounds per square inch	Revolutions per minute	Total number of revolutions	Final temperature		Rise in temperature		Friction	Loss in weight	Remarks
			°C	°F	°C	°F	Pounds	Grams	
100	694	12 230	89	192	53	95	22	0.023	
200	706	16 510	102	216	58	104	29	.021	
300	682	15 150	125	257	100	180	38	.013	Belt slipping
400	603	6 600	139	282	94	169	79	.054	Bearing seized and smoking

ULCO HARD METAL

100	710	13 160	56	133	23	41	13	0.013	
200	715	18 870	69	156	33	59	18	.021	
300	719	18 830	80	176	42	76	27	.013	
400	711	17 310	81	178	43	77	23	.022	
500	723	17 660	79	174	43	77	25	.014	
600	692	14 960	84	183	45	81	24	.021	
700	648	24 520	62	144	38	68	24	.020	
800	365	12 870	53	127	20	36	23	.010	
900	408	22 300	59	138	22	40	24	.015	
1000	405	23 200	66	151	35	65	22	.014	Bearing still in good condition

Large quantities of phosphor bronze of the compositions 80 per cent copper, 10 lead, and 10 tin, and deoxidized with phosphorus, are used in unlined bearings at fairly high speeds and pressures. The following compositions have been suggested as substitutes for this composition, although it is our opinion that trouble will sometimes be experienced with Nos. 8, 9, and 10 because of the high lead content, and they have about the same tin content as the others in the list:

Ingredients	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12
Copper	81	79	74	64	Remainder	Remainder
Tin	7	5	5	5	8	5
Lead	9	15	20	25	15	17.5
Zinc	3	.....	.....	.....	1.5–3	5
Antimony	.....	.....	.....	5	.....	.....
Phosphor copper	.....	1	1	1	.....	.....

III. STANDARD GRADES OF BABBITT METAL

At a meeting called by the conservation division of the War Industries Board on April 15, 1918, which was attended by manufacturers and users of bearing metals, the Bureau of Standards was requested, after conference with technical representatives of the large manufacturers and users, to determine if four classes of babbitt metal could be adopted ranging in tin content as follows:

A (genuine babbitt)	89 per cent tin.
B	40 to 50 per cent tin.
C	4 to 6½ per cent tin.
D	No tin.

The Bureau has gone over the situation with several of the representatives as noted above, and the general opinion seems to be that it is impossible to limit some of the classes to a single composition, because of the fact that several compositions of nearly the same tin content are in general use for different purposes. Thus, in the table below, No. A1 is used in aircraft engines, No. A3 is used for automobile engines, and No. A4 is found in bearings of electrical machinery. It was thought, however, that Class B can be entirely dispensed with, as these intermediate tin content-bearing metals are in no way as satisfactory as either a high lead or high tin base babbitt. In all cases where Class B could be used, Class C or Class D will be found to serve the purpose equally as well. There are, however, some grades of babbitt containing about 65 per cent of tin which do not fall into either Class A or Class B, but which are often claimed by the manufacturers to equal the high tin babbitt in performance. If these claims can be substantiated, this babbitt should be considered as falling into the category of Class A and as being a substitute for alloys in that class.

It should not be presumed that because high tin babbitt of Class A are included that the Bureau recommends the continuance of its use for many bearings in which it is now used. The lowest possible tin-content alloy should always be used, and the Bureau believes that it might be advisable to have some central body issue licenses for the use of babbitt in Class A in order to insure that no Class A babbitt is being used where others are satisfactory.

Alloy D2 has been included in Class D because this comprises babbitt metals containing no tin. It should be noted, though, that this alloy will be found satisfactory in many installations

where Class A has hitherto been used, and its inclusion in class D should not give the impression that it is a low-grade babbitt.

The American Society for Testing Materials has drawn up specifications for 12 compositions of babbitt metals (B23–18T) which, however, do not take into consideration the factor of tin conservation, but are formed for use in peace times. The present recommendations are for use in the existing situation where the saving of all tin possible is of prime importance.

The recommended compositions for the various classes are given in the table following. These compositions have been selected so as to include existing specifications and usage of babbitt metals as far as possible. Much information has been secured from the questionnaire sent out by the Bureau and from replies to the general letter issued by the War Industries Board on May 29, 1918.

Class	No.	Tin	Antimony	Lead	Copper	Iron [a]	Arsenic [a]
		Per cent	Per cent	Per cent	Per cent		
A	A1	91	4½	[a] 1.00	4½	0.08	0.10
	A2	89	7½	[a] 1.00	3½	.08	.10
	A3	84	9	[a] 1.00	7	.08	.10
	A4	83	8½	1.00	8½	.08	.10
C	C1	5	10	85	[a] 50	.....	.20
D	D1	.....	13	87	[a] 50	.....	.25
	D2	Lead about 98 per cent, balance alkali and/or alkali earth					

[a] Maximum.

More than traces of impurities other than those listed above will not be allowed; the following variations above or below the specified amount will be permissible for the desired elements:

Per cent of elements specified	Permissible variations over or under the specified value units of per cent
Not over 5 per cent	0.50
5 to 10 per cent, inclusive	.75
Over 10 per cent	1.00

IV. STRUCTURAL BRONZES

Passing now to the bronzes other than those used for bearing purposes, we find that "Government bronze" (Navy Specification 46M6a, gun metal) of 88 per cent copper, 10 tin, and 2 zinc, is used in large quantities and can also be modified to admit of a saving

of tin without impairment of the physical properties sought. Experiments by the Bureau of Standards and others have shown that a composition of 88 per cent copper, 8 tin, and 4 zinc, is equal to or superior to the ordinary Government bronze. Aluminum bronze of composition 90 per cent aluminum and 10 per cent copper, for example, can also be substituted for many uses of Government bronze, as can also manganese bronze and naval brass. There have also been introduced several aluminum bronzes containing small amounts of iron, which can be either cast or wrought and which are now being used by several former users of Government bronze.

Some manufacturers have raised an objection to using aluminum bronze because the scrap accumulating from this alloy, if it gets mixed with other metals, particularly valve metals, would have a deleterious effect upon them. This is simply a problem in works management of properly sorting and routing scrap. We know of several large manufacturers who make aluminum-bronze castings in the proximity of steam metal castings and who by taking the proper precautions have encountered no difficulties.

The following table gives some of the properties of the above-mentioned alloys:

Alloy	Tensile strength	Elastic limit	Elongation in 2 inches	Authority
	Lbs./in.²	Lbs./in.²	Per cent	
Government bronze, 88 Cu, 10 Sn, 2 Zn.	38 860	12 250	25.2	Average of 30 tensile specimens poured in 5 different foundries. Tensile tests made at the Bureau of Standards.
88 Cu, 8 Sn, 4 Zn	39 220	11 000	30.6	Same as above, except that it represents only 26 specimens.
Aluminum bronze	71 000	25 000	21	Corse & Comstock, Trans. Soc. Autom. Eng., 1916, Part II, pp. 272–273.
Manganese bronze, U. S. N., Mn.	70 000	35 000	30	Navy Department specification 46B15.
Naval brass	[a] 54 000 [b] 60 000	25 000 27 000	40 35	Navy Department specification 46B6b.
Aluminum bronze with iron (Sillman bronze):				
Wrought alloy [c]	84 400	14 000	11.5	Bureau of Standards test.
Cast alloy	78 850	11 500	14.5	Do.

[a] Over 1 inch.
[b] Below ½ inch.
[c] Chemical compositions: Cu, 86.4 per cent; Al, 9.7 per cent; Fe, 3.9 per cent.

At the suggestion of the Imperial Electric Co. of Akron, Ohio, the Bureau also made tests on Government bronze in which one-half of the tin was replaced by an equal amount of nickel. The

averages of several tests on these alloys are shown in the table below.

Composition	Ultimate strength	Yield point	Elongation in 2 inches	Reduction in area	Modulus of elasticity
	Lbs./in.²	Lbs./in.²	Per cent	Per cent	Lbs./in.²
Cu 88, Sn 5, Ni 5, Zn 2	40 680	13 050	31.8	28.0	17 300 000
Cu 89, Sn 4, Ni 4, Zn 3	39 675	11 500	31.2	31.2	14 900 000

It will be observed that the above values are exceedingly good for this class of material and that either of the above alloys can be used as a means of conserving tin.

Many small machine-parts castings are made of bronze, which can just as readily, or even sometimes better, be manufactured of a brass composition—i. e., copper-zinc alloys. Tin is also looked upon in many brass foundries as a "cure-all" for poor castings and is often added to the mixture when trouble is encountered. This practice is not only questionable and should not obtain in brass foundries, but the cause of the poor castings should be determined and the proper remedies applied in a regular manner.

V. SOLDERS

The composition of solders will vary with the use for which the solder is intended. Formerly, every mechanic believed that nothing was as good as "half-and-half," or 50 per cent tin and 50 per cent lead solder. There are very few cases where a 50–50 solder is necessary in the present emergency; its use should be eliminated. No solder over 45–55 should be used for hand soldering with the iron and in the majority of cases 40–60 will serve the purpose. Most plumbers use 40–60 for making wiped joints, whereas 37½–62½ is for all such purposes just as satisfactory. Up to 1½ per cent of the tin in a wiping solder can be replaced by antimony, although this element is objectionable if present in solder for other purposes.

In the manufacture of automobile or airplane radiators very little solder need be used of greater tin content than 40 per cent, and in many cases 35–65 or lower is being used with success. For the canning industry, both in the manufacture of the can and in its sealing, 37½–62½ solder can be used with satisfactory results. Articles which are tinned previous to soldering can be "tinned" in a bath composed of the eutectic of tin and lead—63 per cent tin and 37 per cent lead. This composition will be found to be fluid and will not segregate, as will certain other tin-lead baths.

VI. CADMIUM AS TIN SUBSTITUTE[1]

Cadmium appears as a promising substitute for part of the tin in solders. The Bureau has been developing such a solder, and laboratory test, together with manufacturing experience, so far point to a composition of 80 per cent lead, 10 per cent tin, and 10 per cent cadmium as being practical for many of the purposes for which solder is required. This solder has been tried in the manufacture of tin cans, on roofing materials, and for electrical joints, with encouraging results in all cases. Before using it for food containers, however, it will be necessary to ascertain its toxic properties under various conditions. A test has also been made of it in the manufacture of automobile radiators with most satisfactory results.

The tensile strength of the cadmium solder is about the same as that of 40–60 solder, but the ductility is approximately twice that of the ordinary solders. The point of complete liquidation is only slightly higher than that of the ordinary composition of solders, while the range of solidification is considerably greater. The following table gives some of the provisional data on these solders as compared to the tin-lead solders. The tensile properties given are the average of four determinations and were made on a Scott testing machine, the rate of separation being about 12 inches per minute.

Physical Properties of Cadmium-Lead and Tin-Lead Solders

	Initial solidification	Secondary solidification	Final solidification	Specific gravity	Equivalent volume to 1 volume 50–50 solder	Tensile strength	Elongation in 2 inches
	°C	°C	°C			Lbs./in.²	Per cent
50 per cent tin and 50 per cent lead	[a] 210	[a] 181	[a] 149	8.81	1.00	5698	20.3
40 per cent tin and 60 per cent lead	[a] 238	[a] 181	[a] 149	9.47	1.07	5820	26.0
37½ per cent tin and 62½ per cent lead	[a] 245	[a] 181	[a] 149	9.54	1.08	5383	28.8
90 per cent lead and 10 per cent cadmium	[b] 267	.....	[b] 249	11.09	1.26	5000	37.5
80 per cent lead, 10 per cent cadmium, and 10 per cent tin	254	183	143	10.35	1.17	5727	52.3
85 per cent lead, 10 per cent cadmium, and 5 per cent tin	257	202	141	10.67	1.21	([c])	([c])
75 per cent lead, 10 per cent cadmium, and 15 per cent tin	([c])	([c])	([c])	10.26	1.16	5880	41.7

[a] Rosenhain and Tucker, Phil. Trans., A. 209, p. 89; 1918.
[b] Kapp, Drudes Ann., 6, p. 754 (1901).
[c] Not determined.

[1] For most of the experimental data on cadmium solders the authors are indebted to L. J. Gurevich of the metallurgical staff of the Bureau.

Because of the preponderance of lead in the cadmium solder, the price of it is very reasonable; with the present market prices of the metals involved it is thought that the 80–10–10 solder can be sold at a profit of 35 cents a pound. It is also thought that plenty of cadmium can be produced as soon as the market for it is created, as there are undoubtedly available American sources of cadmium which are not at present exploited.[2]

In meetings with manufacturers of materials containing tin it is always brought out that the Government is the worst offender, and that many Government specifications often call for a lavish use of tin which is sometimes detrimental to the quality of the material manufactured. We believe, however, that many of these specifications are being revised in order to conserve tin, but that there is still room for further improvement. As a means of conserving the use of tin by the Government, we would suggest the advisability of creating a joint committee of technical representatives of the various departments to pass upon or revise all Government specifications containing tin. Such a committee could be in close cooperation with the manufacturers and would form a better means for the manufacturers to criticize the tin content of Government specifications than now exists in any of the departments.

WASHINGTON, October 21, 1918.

[2] See C. E. Siebenthal, Cadmium in 1917, Mineral Resources of United States, Pt. I, p. 49–53; 1917.

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