TEMPERATURE DETERMINATIONS BY EUTECTIC ALLOYS.

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The melting points of pure metals give definite and sharply defined temperature points, and as such are of use in locating standard temperatures, and in the calibration of temperature measuring devices. As the melting points of eutectic alloys also occur at definite and sharply defined temperature points, it appears that eutectic alloys may be useful in temperature standardizations and measurements, and, due to their particular characteristics, may even be more convenient and therefore preferable to pure metals, especially in industrial applications.

As there are many more eutectic alloys than pure metals, and the former cover a wider range of temperatures, the use of eutectic alloys would give a far closer temperature scale, permitting their use not only for standardization of temperature measuring devices, but to some extent even directly for temperature measurements.[1] The foremost advantage expected from eutectic alloys was the far greater independence of their melting point from the purity of the material. With a pure metal, the melting point is very greatly affected, almost always lowered, by even small traces of impurities[2] and a very high degree of purity thus is essential. This greatly limits the availability, requires a high degree of care and precaution in the use, in guarding the material against contamination, and often limits its repeated use, thus making the use of pure metals for temperature calibration rather more a laboratory matter.

A eutectic alloy is that composition of constituents, which has the lowest melting point. Hence it is to be expected that any impurity, even when fairly considerable, should not affect the melting point. Any impurity, such as an excess of one or more constituents, would, in cooling, crystallize out when the freezing point is approached and the alloy thus thickens before solidifying, but the final freezing point remains that of the eutectic alloy. Inversely, in heating, only the eutectic would melt at the critical temperature, any impurity remain solid, and the alloy becomes very fluid only some degrees above the melting point, although the temperature of the melting point itself should not be affected.

Some experiments were then made, in the usual manner by the deter-

[1] The above investigation was suggested by the industrial problem of measuring maximum temperatures existing locally at the rim of steel discs revolving at such extremely high peripheral speeds that centrifugal forces precluded the attachment of any temperature measuring device to the rim of the rotor (steam turbine alternator) at which the temperature was desired. By drilling a series of small holes into the rim of the rotor at those places, where the temperature is desired, and filling the same with various eutectic alloys, the local temperature is located between the melting points of the two successive eutectics, of which the one is melted and thrown out centrifugally, while the next higher one remained.

[2] Thus 1% of zinc lowers the melting point of tin by about 4°.

mination of the cooling curves, to see whether and how far the melting point of eutectic alloys is affected by impurities. The alloy was melted and allowed to cool, while stirring with the thermometer, and every 15 (or 30) seconds the temperature recorded, and temperature plotted against time. The thermometer was checked against a standard calibrated by the Reichsanstalt. Alloys with melting points below 200° were used, partly as they permit melting in test tubes and the use of mercury thermometer for temperature measurements, and also because a series of low melting eutectic alloys was desired by the industrial problem which led to the investigation. A very great tendency to undercooling was found with many alloys, and had to be counteracted by stirring.

The deviation of the alloy from a eutectic may be due to

(1) A deficiency of one or more of its constituents.

(2) An excess of one or more of its constituents.

(3) The presence of some metal which is not a constituent of the eutectic alloy.

All three cases were investigated and are shown by the cooling curves in Figs. 1, 2 and 3.

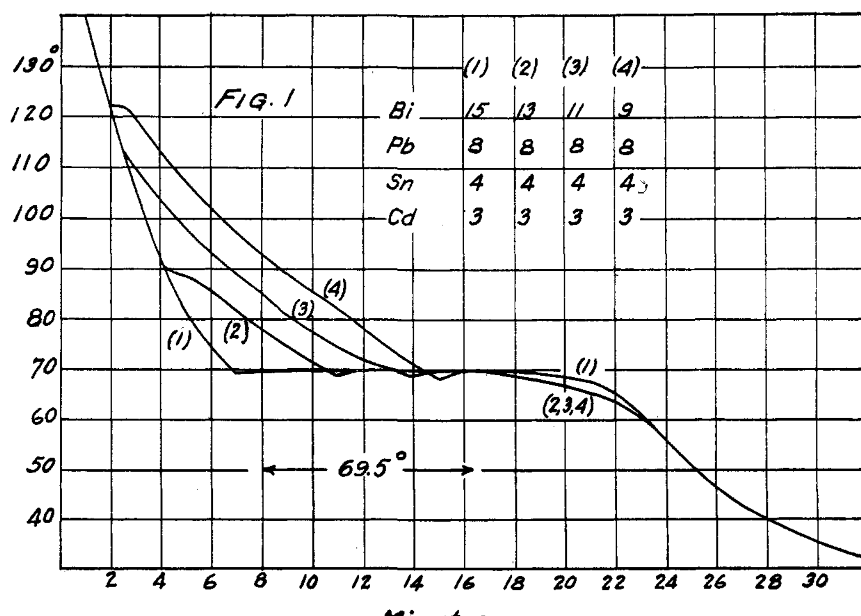


Fig. 1 shows as (1) the eutectic alloy, usually called Wood's Metal,

$$\text{Bi} \div \text{Pb} \div \text{Sn} \div \text{Cd} = 15 \div 8 \div 4 \div 3, \qquad (1)$$

giving a very long and sharply defined horizontal range at the temperature of 69.5°.

(2), (3) and (4) of Fig. 1 differ from (1) by successively greater deficiency of bismuth, up to 20% of the total alloy.

$$\begin{aligned} Bi \div Pb \div Sn \div Cd &= 13 \div 8 \div 4 \div 3 \qquad (2) \\ &\quad\ 11 \div 8 \div 4 \div 3 \qquad (3) \\ &\quad\ 9 \div 8 \div 4 \div 3 \qquad (4) \end{aligned}$$

As seen, the horizontal range successively shortens, and is preceded by a temperature range, during which the alloy gradually thickens; but the final freezing point, 69.5°, is not appreciably changed, though less marked.

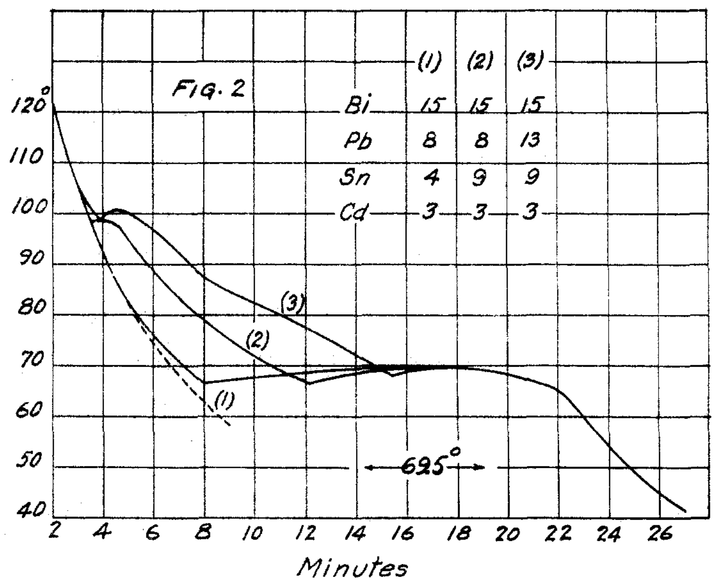


Fig. 2 shows as (1) the same eutectic alloy as (1) in Fig. 1, except that, due to insufficient stirring, considerable undercooling has taken place, and in freezing the temperature only gradually rises to the normal melting point, 69.5°.

(2) gives the same alloy with the addition of five parts (16.7%) of tin, and (3) the same alloy with the addition of five parts (16.7%) tin and five parts (16.7%) lead. That is,

$$\begin{aligned} Bi \div Pb \div Sn \div Cd &= 15 \div 8 \div 4 \div 3 \qquad (1) \\ &= 15 \div 8 \div 9 \div 3 \qquad (2) \\ &= 15 \div 13 \div 9 \div 3 \qquad (3) \end{aligned}$$

The characteristics are the same as in Fig. 1, a shortening of the constant temperature range during freezing, and an increasing range of gradual thickening, at gradually falling temperature, preceding the final freezing. However, the temperature of the final freezing point is not appreciably changed from 69.5°.

(1) in Fig. 2 was a different sample of Wood's metal from that in Fig. 1, and apparently less pure as eutectic, showing a slight deviation from the exponential cooling curve (shown dotted) when approaching the freezing point.

Fig. 3 shows as (1) the alloy

$$Pb \div Sn \div Cd = 5 \div 3 \div 2 \qquad (1)$$

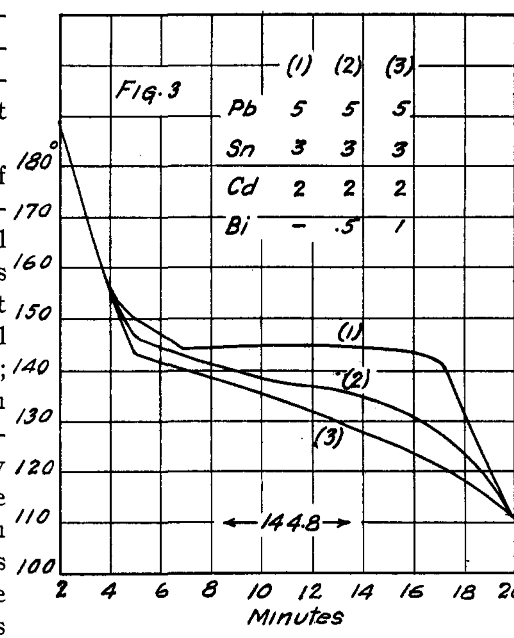
with a sharply defined freezing point at 144.8° and as (2) and (3) two alloys produced by the addition of 5% and 10% bismuth, respectively.

$$Pb \div Sn \div Cd \div Bi = 5 \div 3 \div 2 \div 0.5 \qquad (2)$$

$$= 5 \div 3 \div 2 \div 1 \qquad (3)$$

Here, by the addition of a considerable quantity of a metal which does not belong in the eutectic alloy, the sharply defined freezing point disappears, the freezing temperature is lowered, and freezing occurs by a gradual thickening of the alloy throughout a temperature range.

Therefore in the use of eutectic alloys for temperature determinations, material impurities caused by metals which are not a constituent of the alloy, may be harmful and are to be guarded against; but a considerable deviation of the proportions of the normal constituents of the alloy appears harmless. Even the harmful effect of a foreign metal impurity probably is limited to the cases where the addition of such metal forms a eutectic alloy of lower melting point. For instance, the addition of zinc to the alloy (1) in Figs. 1 and 2 apparently has no effect in lowering the melting point, but merely causes a thickening of the alloy when approaching the freezing point.



When looking up the literature for eutectic alloys of low melting point, records of a large number were found, but most of them proved not to be eutectics, and the given melting points were frequently erroneous, due to disregarding the undercooling of the alloy.

The following twelve alloys were found in the range below 200°, which are eutectics or sufficiently near to eutectics in their composition, to permit their use, and their melting points determined by observing the freezing curves, while stirring with the thermometer. A number of observations were made with each alloy, with slightly changed composition, and by interpolation the composition of the true eutectic estimated and checked by its freezing curve.

However, neither time nor facilities were available to go very far in the investigation, and the values given in the following table thus are only approximately those of the eutectic. It would be of interest to determine the exact composition of the eutectic. This could most conveniently be done by studying the shape of the cooling curve. In the eutectic, the curve of decreasing temperature of the melted alloy follows an approximate exponential down to the constant freezing temperature, as in (1) of Fig. 1. If, however, the composition is not exactly eutectic, the cooling curve deviates from the exponential when approaching the freezing point, and the temperature decreases more slowly, while the non-eutectic part freezes out, as specially markedly seen in (1), Fig. 3 for instance.

LOW MELTING EUTECTIC ALLOYS.

(Approximate.)

Melting point.	Composition.						Remarks.	Temp. of undercooling.
	Bi.	Cd.	Pb.	Sn.	Tl	Zn.		
69.5[1]	15	3	8	4	..	..	slightly ductile	64°
90.0	7	1	6	..	..	..	ductile	83
93.5[2]	2	..	1	1	..	..	moderately ductile	91
102.4	11	4	..	5	..	..	brittle	96
132.0	11	..	9	..	..	..	ductile	127
132.5	2	..	..	1	..	..	brittle	..
143.5[3]	2	1	..	..	..	..	brittle	137
144.8[4]	..	2	5	3	..	..	ductile	137
166.5	..	..	..	4	3	..	ductile	..
172.0	..	1	..	2	..	..	ductile	..
178.3[5]	..	..	3	5	..	..	ductile	175
194.0	..	..	..	10	..	1	ductile	..

It is interesting to note that the alloys which do not contain bismuth are ductile, while the alloys containing bismuth are brittle, unless they contain a large percentage of lead and little if any tin or cadmium.

SCHENECTADY, N. Y.

[1] Wood's metal, expands after cooling.
[2] Rose metal, expands after cooling.
[3] Combustible above melting point.
[4] Cadmium solder. Lowest melting alloy not containing the expensive bismuth.
[5] Tin solder.