LEAD INDUSTRIES ASSOCIATION

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NEW YORK 17, N. Y.

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SUBJECT: SUMMARY OF RESEARCH REPORT

To Members of the Lead Industries Association:

You may be interested in the attached reprint, which summarizes the results of a research project sponsored by LIA in 1958 and terminated in December of that year. Additional copies are available as long as our limited supply lasts.

Very truly yours,

Secretary

Att.

A New Class of Lead-Base Alloys

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Experimental work indicates that dispersing a metal powder in lead improves its tensile properties. Made by stirring powders of low solubility such as copper, nickel and cobalt into molten lead, the new alloys show promise in extending the usefulness of the heavy metal. (C5r, Q27a, R6g; Fb)

Lead has two characteristics which are relatively unusual in a metal – low melting temperature (621° F.) and low solubility for most of the other metals. This has led to the concept of forming two-phase alloys of lead and another metal by direct mixing of molten lead and finely divided powdered metal. Such alloys might prove useful from the standpoint of improved properties of the lead base and some special characteristics of the second phase additive.

An exploratory study of the feasibility of forming alloys of this type – referred to hereafter as lead-cemented alloys – has been conducted at Battelle Memorial Institute in cooperation with the Lead Industries Association. Results of this study are presented here.

Selection of Alloying Materials

Lead-cemented alloys are prepared by direct mixing of a finely divided solid phase in molten lead. This procedure will work satisfactorily only if certain requirements are met. Foremost among these are low solubility and good wettability. It is essential that the finely divided solid material not dissolve in molten lead to any appreciable extent. At the same time, to enhance mixing of the solid and liquid phases, good wettability is required. This is most easily obtained if a slight degree of solubility exists. Fortunately, a number of metals such as cobalt, copper, iron, molybdenum, nickel and tungsten show the requisite low solubility in molten lead for satisfactory alloying. All of these metals are easily obtainable in powdered form.

The composition of the lead phase could also be varied over a considerable range, with either alloying elements completely soluble in both liquid and solid lead or with alloying elements which form eutectics or precipitates in solid lead. However, the present investigation was limited to the use of an unalloyed high-purity lead base.

Mixing Procedures

The most satisfactory mixing procedure is determined by the amount of solid material to be added. For relatively small additions – up to about 15 vol.% – high-speed propeller mixers are satisfactory. When the amount of solid material is greater, the mixture becomes quite sluggish, with the characteristics of a wet cement. These mixtures are best prepared by use of a slowly revolving crucible modeled after a cement mixer. A drawing of equipment for preparing lead-cemented alloys having

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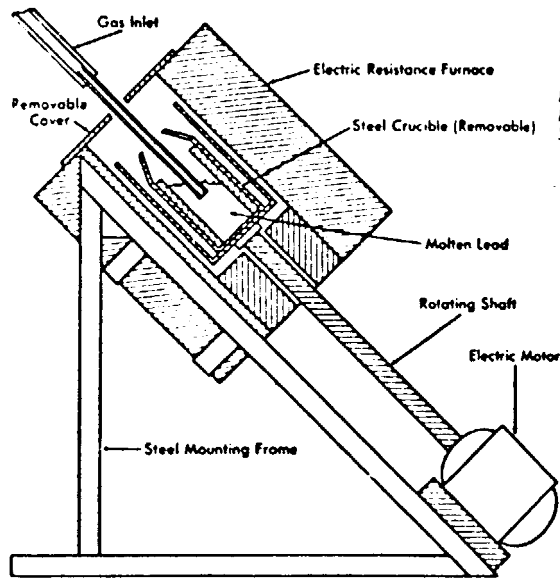


Fig. 1 – Apparatus Used to Prepare Lead-Cemented Alloys Containing More Than 15 Vol.% Solid Material

more than 15 vol.% additive is shown in Fig. 1.

Some of the metals – notably copper and nickel – stir quite easily into molten lead. Others, however, resist mixing attempts because of an oxide film on the powder surface. By reducing the oxide with hydrogen, and mixing under hydrogen, these difficulties were overcome. (Note provision for maintaining a hydrogen flame over the melt in Fig. 1.) These procedures in conjunction with a high mixing temperature permitted the introduction of a number of metals into molten lead.

The amount of powder added to the lead was varied from less than 15 to more than 50 vol.%; it was added directly to the melt, a small amount at a time, until mixing was complete.

Characteristics of the Alloys

The dispersion of solid metal powder in molten lead was cast directly from the mixing crucible into an ingot mold and solidified rapidly to prevent gravity separation. Porosity was minimized by vibrating the mold at low frequency until the metal solidified. After being scalped to remove surface defects, the ingots were extruded to rod at 500 to 550° F. Extrusion of the alloys generally proceeded satisfactorily. If mixing was incomplete, however, so that pockets of unwet powder were present in the ingot, severe surface cracks often formed during extrusion.

Metallographic examination of the extruded bars shows that the cemented alloys consist of a uniform dispersion of metal powder in a lead matrix. No deformation of the metal powder seems to occur during extrusion. Figure 2 shows a typical structure. Very little of the metal powder dissolves during mixing but some agglomeration of particles is evident.

As shown in Table I, metal powders generally improve the tensile strength of lead. Excessive agglomeration apparently caused the low strength of the cemented alloy which contains iron.

Although a complete study of the effect of powder size, shape and amount on tensile strength was beyond the scope of this investigation, some interesting trends are apparent in the data given in Table I. An optimum composition seems to exist for each powder used.

Table I – Tensile Properties of Several Lead-Cemented Alloys*

Composition	Strength	Elongation	Reduction of Area
Unalloyed lead	1940 psi.	65%	98%
Nickel, 30 vol.%	5130	12	22
Nickel, 15	2480	10	15
Copper, 30	4050	6	9
Tungsten, 30	4450	14	26
Iron, 30	1670	3	6
Cobalt, 30	3110	9	19
Cobalt, 18	4820	12	26

*0.505-in. bar samples tested at a crosshead speed of 0.02 in. per min.

Table II – Corrosion of Lead-Cemented Alloys in H_2SO_4 at 140° F.

Composition	Weight Loss in 96 Hr.*	
	40% H_2SO_4	95% H_2SO_4
Unalloyed lead	0.092 g./sq.in.	4.887 g./sq.in.
Copper, 30 vol.%	0.156	14.510
Cobalt, 18	0.112	1.820
Tungsten, 30	0.170	4.900

*Sample size, ½ in. diameter by 2 in. long.

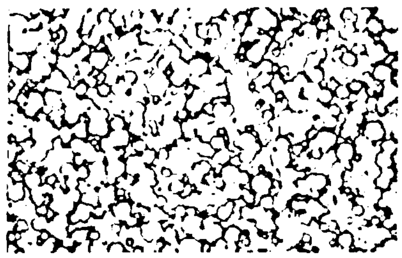


Fig. 2 – Typical Structure of an Extruded Lead-Cemented Alloy. This one contains 30 vol.% Ni. Although nickel particles have agglomerated to some extent, their shape is not changed by extrusion. 250 ×

For example, an alloy of 18 vol.% Co is superior to one containing 30 vol.% Co, but 30 vol.% Ni is superior to 15 vol.% Ni. Also, properties are improved most when a more spherical powder shape and a finer particle size are used. Results obtained in this study suggest strongly that amount, size and shape of the powder are appreciably more significant in controlling tensile properties than composition of the powder.

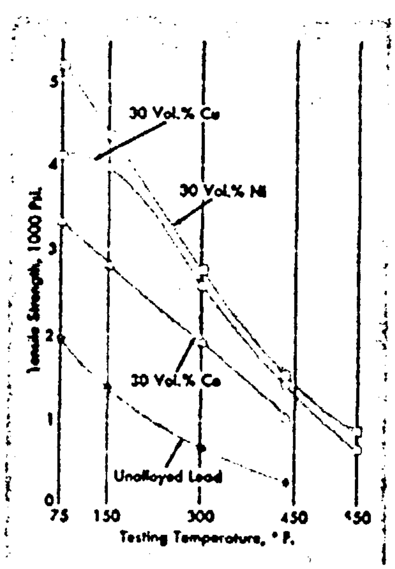
The tensile properties of several cemented alloys as a function of temperature were also determined. Representative data are given in Fig. 3. The ability of the lead-cemented alloys to retain strength at elevated temperature is of considerable interest. If a similar benefit is observed in creep loading (no creep studies have been made), alloys of this type should raise the upper temperature limit to which lead alloys can be used.

Measurements were also made to determine the effect of the dispersed metal phase on the resistance of the alloys to corrosion in sulphuric acid at two concentrations, 40 and 95 vol.%. These data are shown in Table II. Corrosion resistance of the lead-cemented alloys is generally inferior to that of unalloyed lead. However, the corrosion rate decreases more rapidly with time in the cemented alloys than in unalloyed lead, possibly due to the dispersed powder which may cause tight adherence of the corrosion product. One alloy with 18 vol.% Co was superior to lead in 95 vol.% sulphuric acid concentration.

Extruded lead-cemented alloys machine better than unalloyed lead. This suggests the possibility that these alloys may be amenable to joining with threaded joints.

The present study was intended to show the feasibility of producing a new class of lead alloys, the lead-cemented alloys. The next step is to develop alloys toward specific uses. For example, the data already available suggest that certain alloys may be especially useful in the chemical industry as corrosion resistant alloys capable of bearing greater stresses at higher temperatures than present alloys. The structures may also be of interest in bearing-metal applications. Alternately, applications may be based upon some special characteristics of the dispersed phase – the magnetic characteristic of iron powder, for example – with lead serving principally as a binder to permit easy casting and fabrication. Most materials, both metallic and nonmetallic, could probably be made sufficiently wettable to permit their introduction into lead. Or perhaps special uses may be developed which are uniquely suited for these alloys. A hypothetical example is a duplex radiation shielding material for use at elevated temperature, where both components of the alloy provide a specific shielding characteristic, and the structure of the alloy provides the necessary resistance of flow.

Fig. 3 – Tensile Strength of Several Lead-Cemented Alloys as a Function of Temperature



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