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LEAD INDUSTRIES ASSOCIATION

420 LEXINGTON AVENUE

NEW YORK 17, N. Y.

METALLIC LEAD PRODUCTS DIVISION

see Lead Chemical Construction Bull. No. 12

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To Members of the Metallic Lead Products Division:

Attached is a reprint of the section on lead and lead alloys prepared by the Lead Industries Association and published in the October issue of "Industrial and Engineering Chemistry," official publication of the American Chemical Society.

The enclosed section is part of the Eighth Annual Materials of Construction Review. This reprint is also being mailed, as one of our series of Chemical Construction Bulletins, to our mailing list of approximately 1300 chemical construction companies, chemical engineers, chemical engineering professors, and others interested in chemical construction.

Additional copies are available as long as our supply lasts.

Yours very truly,

Robert L. Ziegfeld

Secretary.

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Eighth Annual Materials of Construction Review (1954)

LEAD AND LEAD ALLOYS

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Lead and Lead Alloys

KEMPTON H. ROLL, *Lead Industries Association, 420 Lexington Ave., New York 17, N. Y.*

The lead supply situation continues much as it was last year. Physical and mechanical properties of lead and lead alloys, particularly creep characteristics, have been determined. The effects of purity and additions of antimony, tin, copper, arsenic, bismuth, zinc, magnesium, calcium, tellurium, thallium, and silver on the creep characteristics of lead were investigated. New engineering applications of bonded or clad lead linings on steel and copper were described. The performance of lead equipment in the handling of liquid alum and other corrosives was covered along with some applications for lead in modern architecture where resistance to atmospheric corrosion is paramount. Lead coating as a means of prolonging the service life of steel equipment exposed to sulfuric acid was described. The use of lead for radiation protection was compared with other possible shielding materials. The technique of using a cartridge powered stud driver for anchoring sheet lead and steel strapping to steel or concrete vessels has been put to practical use in the field resulting in substantially reduced sheet lead lining erection cost. Corrosion performance and other characteristics of lead-tin alloy coated strip steel were described along with several patents facilitating the manufacture of bonded lead-lined equipment, bonded lead covered pipe, and the lead coating of ferrous objects.

MARKET conditions are such that the users of lead are assured a continuing supply free of government restrictions and at a price competitive with other materials of chemical construction. In fact, the current potential supply of lead is actually in excess of what is being consumed.

Noteworthy technical advancements have been made in the installation of lead, particularly in strapped sheet linings and in utilizing lead claddings whereby the corrosion resistance of lead can be combined with the working strength of steel or conductivity plus strength of copper. A number of excellent papers on the behavior of lead and lead alloys in engineering applications have been published.

RESEARCH PROGRESS

Lead Alloys. Hopkin and Thwaites (*11*) of the British Non-ferrous Metals Research Association laboratories showed that if 99.994% pure lead is used to make a 1% antimonial alloy, no age hardening effect can be produced. In the course of an investigation of the creep and fatigue properties of lead and lead alloys, a binary alloy with 0.85% antimony was extruded from a specially refined billet. Impurities detected in the lead amounted to only 0.0002%. No estimation of oxygen content were made.

After extruding the alloy to rod and aging it at 20° C. no hardening was observed even after 12,000 hours at 175° C. and water quenching. In fact, it did not age harden even after 20,000 hours at 80° C. or 770 hours at 100° C.

According to Hopkin and Thwaites neither tin nor copper added in amounts of 0.01% to the pure alloy produced any detectable age hardening. On the other hand, as little as 0.001% arsenic caused age hardening to proceed as effectively as it does in commercial alloys. The addition of 0.001% arsenic, moreover, had just as great an influence on the rate of age hardening as had larger amounts to 0.02%. The only other element that induced age hardening was silver, but it was possible to produce some hardening by prestraining the specimens.

Brown and Jones (4) of the Naval Research Laboratory in dealing with microsegregation in antimonial lead alloys were particularly concerned with the effects of microstructure on the corrosion of lead-antimony alloys and of nearly pure lead when used as the plates of lead-acid batteries. With as little as 0.04% antimony, there was pronounced segregation in slowly cooled alloys. Only chill cast alloys showed a normal eutectic structure and of the chill cast samples only those containing 13% antimony showed 100% eutectic in the microstructure. Slowly cooled alloys, on the other hand, never showed a normal eutectic structure, whatever the composition.

Research progress in antimonial lead alloys was summarized in two issues of *Metal Industry* by Recorder II (*21, 22*). The investigations of Hopkin and Thwaites and Brown and Jones were reviewed and correlated with that of previous investigators.

Lohberg (*19*) surveyed the relationship between the melting point of various nonferrous alloys and the temperature at which creep begins. The various means by which creep resistance can be increased are reviewed. Studying the effect of alloying additions on lead alloys showed that antimony and bismuth in the order of 0.1% each affect the creep resistance of lead unfavorably or not at all. The more favorably reacting metals include zinc, magnesium, and calcium which are dissolved by lead only in quantities of less than 0.1%. The improvement in creep with copper is remarkable, requiring less than 0.005%. The paper is of the review type and does not represent an original investigation.

Gefkins (*8*) investigated the influence of thallium additions on the creep of lead. Variations in creep characteristics with thallium concentrations of 0.5%, 0.5 to 9%, over 9%, and 40.5% are plotted.

Loin (*15*) conducted tests both at constant internal pressure and at constant hoop stress on lead and lead alloys in the form of pipe. The results provided some indication of the effects of alloy additions, grain size, and prior deformation on fracture, ductility, and creep of lead cable sheath alloys. Some alloy additions, notably antimony (0.36%) and tellurium (0.04%), appear to promote considerable embrittlement at slow creep rates.

Atkinson and associates (*1*) described the creep and fatigue characteristics of a new arsenical tin-copper-lead alloy used for cable sheathing.

	%
Arsenic	[illegible]
Tin	[illegible]
Copper	[illegible]
[illegible]	[illegible]
Bismuth and Antimony	[illegible]
Lead	Remainder

At a given stress the creep rate for this alloy is lower than for a common copper-lead alloy. The creep rate at hoop stresses below 200 pounds per square inch is not greatly affected by variations in heat treatment which produce a tensile strength in the range between 2300 and 2700 pounds per square inch. Addilined steel is commonly employed. In piping the cost differential between lead and other materials is generally in favor of lead; a factor influencing its selection as a construction material.

ADVANCEMENTS IN TECHNOLOGY

One of the most interesting and practical developments in the lead chemical construction field of recent years was in its preliminary stages last year and briefly described as such in last year's review for Lead and Lead Alloys (30). It involved the use of a cartridge powered stud driver for anchoring sheet lead and steel strapping to steel or concrete vessels. Since that time, the technique has been used in the field and has proved to be a real innovation substantially reducing sheet lead lining erection costs. Strapped lead linings may be erected considerably faster and better than by customary drilling and bolting techniques. The method also eliminates the erecting of scaffolding on the outside of large tanks. The first of several similar articles describing the use of the stud driver on lead linings appeared in the Corrosion Forum section of Chemical Engineering (2).

While the use of bonded lead lining or cladding has in many cases replaced the strapped sheet type of lead lining in chemical construction, because a cladding more effectively combines the strength of steel with the superior corrosion resistance of lead; nevertheless there are many applications where the extra expense of a bonded lead lining is not warranted and where a strapped lining will do the job just as effectively. For this reason strapped lead linings are still recognized as an important method of utilizing lead in chemical construction and any developments making such installations easier or more economical are especially significant. The cartridge powered stud driver is such a development. It is used for securely anchoring steel straps to a lead lined steel vessel without drilling and matching bolt holes or for fastening sheet lead to concrete without requiring other time-consuming and expensive methods.

Pioneering in the application of the cartridge powered stud driver, the Remington Arms Co., (17, 28) in cooperation with the Lead Industries Association, arranged with a number of lead fabricators to test the new device under actual service conditions. Since then Ramset Fasteners, Inc., (27) also entered the field and has contributed several additional innovations.

In general, the cost reductions compared with customary fastening techniques have been about 60%, largely the result of lowered labor costs. For example, the Lone Star Lead Construction Co. in Houston, Tex., installed a lead lining in a 35-ft. tank without having to erect scaffolding on the outside. With the stud driver all the work was done from the inside in less than half the time normally involved. On one job, Knapp Mills, Inc., of Long Island City, N. Y., estimated 300 hours for installing bolted straps, but with the stud driver the time was reduced to 130 hours.

The thickness of strapped lead lining commonly being fastened is through 1/4-inch steel strap, plus 1/4-inch lead lining, plus 1/2-inch steel shell although a newly developed tool has successfully driven fastenings in 1-inch steel tank walls. There is evidence that the thickness of the lead is more or less inconsequential since it appears to behave more as a lubricant for the steel stud than as an impediment. Tests on the strength of the stud have shown that the normal nail-type stud will continue to hold long after a 1/2-inch mild steel nut and bolt would have failed by shearing.

Points of the stud protruding through the outside of the steel tank can be chipped off with a torch, cut off with a special bolt cutter, or covered by a wood facing strip hammered over them.

In a typical strapped sheet lead lined steel vessel, the use of the stud driver eliminates the drilling of the strap and shell, an operation requiring about 12 minutes after marking, and the setup operation which takes about 2 minutes, making a total of 14 minutes for each hole. Setup applies to the erection of the necessary staging and equipment so that the operators can have proper leverage for drilling. Stud driving, on the other hand, takes approximately 2 minutes per hole for loading the gun and shooting the rivet after the setup, making a total of only 4 minutes per hole or a time saving of more than 70%. Furthermore, marking time can be cut considerably because in driving studs, it would not be necessary to adhere to a specific spacing. Studs can be driven virtually at random.

Special "button nuts" 2 inches in diameter have been perfected which eliminate the strapping as such and can be tightened down against the lead with a spanner wrench. Of course, the steel buttons must be in turn covered with lead to prevent corrosion.

Metallizing or the spraying of metals, much as paint is sprayed, has gained considerable recognition as a means of improving the corrosion resistance of the less expensive but more readily corroded metals. An application where sprayed lead was used to particular advantage was described (17). It was concerned with steel battery boxes used for supporting lead-acid storage batteries where, because of the sulfuric acid electrolyte, unprotected steel became severely corroded in a short time. By metallizing with approximately 0.03 to 0.05 inch of lead, sufficient corrosion resistance was provided to enable steel to be used successfully. The article points out, however, that because of its porous nature, metallized or sprayed lead does not successfully serve as a substitute for sheet lead or bonded lead.

The shielded arc welding technique has been extended in one instance to the welding of lead flashings. A fabricator (33) of lead vent pipe flashing units found that shielded arc welding reduced production costs to one quarter the cost of methods previously used. Flashings were welded on a production line basis at an average speed of 20 inches per minute employing an electrode operated at 30 amperes. It produced smooth, uniform welds in lead while eliminating post-welding cleaning steps. However, so far as can be determined, no attempts have been made to apply this type of lead welding to commercial applications in the chemical process industries. Tests that have been conducted indicate definite shortcomings that may be overcome in the future.

Rendl (29) emphasized the superior corrosion resistance of lead-tin alloy coated strip steel. Referring to the 85% lead and 15% tin alloy deposited on strip steel from a recently developed fluoborate solution, he pointed out that strip steel thus coated offers several important fabricating advantages. The coating acts as a lubricant thus reducing wear on dies and forming rolls, its presence substantially reduces post-fabrication plating costs, and it offers excellent solderability. The paper is well illustrated with photographs of the coating operation.

Several British publications described a continuous lead casting machine designed and recently installed by the Fraser and Chalmers Engineering Works of the General Electric Co., Ltd. (4, 26). The machine is being used by a chemical producer and has a capacity of 10 tons of pigs per hour. The machine comprises 88 molds, each holding 2 pigs of 56 pounds each. The molds form a continuous train around the track of the machine somewhat like the chain on a sprocket drive.

NEW PATENTS

Patents were applied for by Knapp Mills, Inc., covering a new method for extruding a bonded lead covering on copper or steel pipe (19). The company reports that the new process is being used to make tubes and rods in small diameters.

After bonded lead tanks are assembled from knocked-down sections and field welded, the welded area must be clad with lead. Since the upright and girth seams are in a difficult position, the work of lead cladding these areas has been tedious and expensive. Patents (18) have been applied for by Knapp Mills, Inc., covering a "walking mold" which molds a lead cladding over a steel weld. The use of this device reportedly simplifies the cladding technique and decreases the cost of this phase of the work.

tional improvements claimed for this alloy include good ductility at both high and low stress, freedom from age hardening, and adequate tensile strength.

Reviewing the use of lead and lead alloys in the field of chemical construction, Lesdler (14) illustrated the improved creep characteristics of silver-copper-lead (0.004% each) over high purity (99.99%) lead.

Physical Properties	Elongation, %	Days
Pipe		
Silver-copper-lead	[illegible]	[illegible]
Pure lead	[illegible]	[illegible]
Sheet		
Lead	[illegible]	[illegible]
Silver-copper-lead	7.5	[illegible]

	Fatigue Strength at 20,000,000 Cycles, Lb./Sq. Inch
Lead	[illegible]
Lead + 0.06% copper	[illegible]
Silver-copper-lead	[illegible]
Copper-tellurium-lead	[illegible]

What is termed silver-copper-lead in Great Britain is approximately equivalent to chemical lead in the United States. Chemical lead, according to ASTM Specification B29, contains 0.02 to 0.002% silver and 0.04 to 0.08% copper with a lead content of 99.90%.

Lesdler illustrated with photomicrographs that joining lead by welding results in the formation of a cast lead structure at the juncture and that therefore the practice of hammering the welds to bring about recrystallization can be recommended as a means of improving the strength of this type of joint.

Lead. Loizou and Sims (20) carried out a series of tests on the yield strength of pure lead in compression as part of a general investigation of hot rolling in which cold lead was used as a model for hot steel. The variation of the yield stress of pure lead in uniaxial compression with temperature, strain, and strain rate was described. Experiments were designed to test the accuracy of the results. The average coefficient of friction between the platens and specimen was measured for lubricated and unlubricated compression, and its dependence on strain rate was demonstrated. The effect of previous strain rate history on the yield stress was also discussed.

The cause and prevention of "barreling" of compression test specimens were discussed. By machining concentric grooves 0.012-inch deep in each end of the specimen and lubricating, barreling can be entirely eliminated. Too few grooves resulted in barreling and too many entrapped so much oil that the ends of the specimen were splayed outward. The optimum was 32 grooves per inch radius.

Metal Industry published detailed abstracts of a German symposium devoted to the hot deformation of metals; the original papers were published in German in *Metall*. A paper by Hofmann (10) was devoted to the hot and cold forming of lead and the determination of the oxygen content of lead by means of the hydrogen reduction method. He emphasized the dependence of oxygen solubility in lead on temperature.

Frisch and Thomsen (7) starting with a 4.3-inch diameter billet of pure lead, extruded it at room temperature to form a 1.5-inch diameter solid bar using three extrusion rates: 0.1, 0.74, and 1.15 inches per minute. Metal extrusion was studied experimentally at various strain rates. Particle velocities, magnitude, and direction for the inverted extrusion process with a sharp-edged die were determined. The flow pattern was invariable with respect to extrusion rates and pressure effects. All characteristics were determined on a meridian plane using a stepwise extrusion method.

The rates of disintegration of lead cathodes into colloidal lead at high current densities in alkaline and weak acid solutions were studied by Salzberg (27) at the Naval Research Laboratory. The cause of this phenomenon is the formation and subsequent decomposition of a volatile unstable hydride of lead, PbH_4.

ENGINEERING APPLICATIONS

A development of Knapp Mills, Inc., involved the successful commercial production of lead plate heaters and direct gas-fired tube type immersion heaters (17). The latter is constructed of lead bonded to steel or copper. Although the melting temperature of lead is 621° F., direct gas-fired immersion heaters are able to operate successfully because of the excellent heat transfer that takes place between the lead and steel or copper when the lead is properly clad.

The use of lead in liquid alum coagulating systems such as those employed in most public water works is described and illustrated in some detail in *Lead*, (19) a publication of the Lead Industries Association. Methods and equipment employed at the Wyandotte water works in Michigan, serve to illustrate the advantages of lead for handling liquid alum, a chemical corrosive to most materials of construction.

One advantage of lead brought out in this particular case was that a concrete vessel that had been discontinued from other service was readily restored to usefulness by lead lining with 10-lb., 4% antimonial sheet lead supported by a lead-covered steel strap. Three-inch lead pipe and other lead fittings were used as fill-line and for conveying the liquid alum to the coagulating unit. Methods of using dry alum instead of liquid and dissolving it on the premises in a lead-lined tank that could double as a storage tank were also cited.

Hoerger (9) described the use of lead as a corrosion resisting material in chemical equipment citing reasons for its high corrosion resistance. He specifically illustrated and gave examples of applications of lead in the German chemical industry.

For many centuries lead has been recognized as an important metal in architecture where it served in a dual role—it provided protection to the buildings through its resistance to atmospheric corrosion, and it provided aesthetic advantages, architecturally speaking. How lead is used in ultramodern architecture is illustrated with drawings and photographs in "Lead" (18) with specific reference to a new private dwelling recently constructed in Randolph, Vt. Lead is used as a facing strip and gravel stop around the edge of the flat roof, as a flashing around all structures extending through the roof such as vent pipes, dormers, and chimneys, as a flashing around a parapet wall, and as a capping protecting the tops of two large chimneys.

An interesting historical observation is brought out in the article—sheet lead was used in the ancient Hanging Gardens of Babylon to protect the famous structure from damage due to seepage and to retain the moisture necessary for the gardens. Fox (6) of Brookhaven National Laboratories discussed the use of lead in nuclear shielding.

The use of lead for shielding in the x-ray region is 10 to 100 times as effective as an equal weight of iron and even more effective than other materials, but as energies increase to about 3 M.E.V., there is very little distinction between lead and iron.

Although the use of lead is more economical in the x-ray regions than at the higher energy levels, lead always has the advantage of greater density and hence is preferable where there are space limitations, such as in atomic powered submarines or airplanes. One of the major uses of lead and one that promises to be still greater in the future is in the manufacture of containers for storing and shipping radioisotopes and for handling them in laboratories. For example, the current requirements for Brookhaven National Laboratories are about 1,000 tons of lead to which can be added 300 additional tons annually, all of it is used for handling radioisotopes.

Whitlock (34) of Ragmuster and Reyer, New York, discussed the use of lead as a corrosion resistant material in chemical construction. In the metal recovery field, the most lead is used where the processes have been in use for longer periods and more is known regarding the best materials of construction. In wet process metallurgical operations, brick- and lead-lined and lead-

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A U. S. patent (25) was issued covering a new method of lead coating ferrous articles. The process involves first electroplating a thin coating of tin between 0.000003 and 0.000018 inch and then heating the tin plated article to 650° F. to melt and transform substantially all of the tin to a continuous layer of iron-tin alloy. Finally the article is dipped in a molten bath of substantially pure lead.

NEW PUBLICATIONS

The Federated Metals Div. of the American Smelting & Refining Co. released a brochure (5) consisting of a comprehensive compilation of data on lead and lead products. Beginning with a description of lead's use as a construction material, the brochure gives the grades of lead used, characteristics and specifications of sheet, pipe, and special fittings including flanges, acid lead valves, and lead-lined valves. Lead welding and construction techniques are also described and illustrated with photographs and line drawings of recommended construction methods for sheet lead and bonded lead-lined installations and for heating and cooling coils. In addition there are handy reference tables and data on lead's behavior with various corrosives along with the important chemical, physical, and mechanical properties of lead and lead alloys.

The National Lead Co. published a brochure showing in considerable technical detail the applications of lead in the chemical industry with special emphasis on its excellent corrosion characteristics (24). Production techniques for all the common lead products, including sheet-lead equipment, pipe, coils, valves, fittings, pumps, lead-lined pipe and lead die castings, are described and illustrated. Cast hard lead and lead-lined valves are specially featured with exploded detail drawings, photographs, and mechanical specifications. Other lead products such as acid recovery equipment and lead bricks used in radiation protection are included in the brochure.

The St. Joseph Lead Co. published a similar booklet on lead (31). Essentially a reference brochure on the properties and applications of lead and lead alloys, the St. Joseph publication also goes into some detail on the use of these materials in architecture, chemical construction, plumbing, radiation protection, cable sheathing, ammunition, solder, bearings, type metal, batteries, tetraethyllead, paint, and glass.

The Lead Industries Association, since the publication of last year's Review, released three more in its series of *Lead Chemical Construction Bulletins*. *Bulletin No. 8* is a flow sheet showing the manufacture of high purity sulfur dioxide from roaster gases (8). The process is based on the absorption and subsequent stripping of sulfur dioxide in dimethylaniline and makes considerable use of lead chemical construction. For example the absorption towers are constructed of 12-lb., 8.5% antimonial lead riveted in cage-type construction, the solution collectors are entirely of 45-lb. lead, and the stripping tower is of lead bonded or clad steel. Unique countercurrent lead pipe heat exchanger coils are illustrated and described.

Bulletin No. 9 reprints the Lead and Lead Alloys Section of the Seventh Annual Materials of Construction Review (1953) which appeared in INDUSTRIAL & ENGINEERING CHEMISTRY (30).

Bulletin No. 10 describes the use of the stud driver in the erection of lead linings.

The Interstate Commerce Commission (12) formulated and published amendments to their regulations for the transportation of explosives and other dangerous articles that became effective December 31, 1953. Some changes of interest to the chemical industry cover the transportation of phosphorus oxychloride, phosphorus trichloride, and thiophosphoryl chloride so as to now include tank motor vehicles when the tanks are lead-lined.

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