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LEAD INDUSTRIES ASSOCIATION

292 MADISON AVENUE
NEW YORK 17, N. Y.

October 16, 1961

SUBJECT: LEAD WELDING CHAPTER

To Members of the Lead Industries Association:

Attached is a reprint on "LEAD WELDING" which is taken from the "Welding Handbook, Chapter 71, Section IV," Fourth Edition, recently published by the American Welding Society.

These booklets are obtainable from us at our cost of 40¢ each.

A member of our staff, Mr. David M. Borcina, was chairman of the AWS Lead Welding Committee that prepared this section.

Sincerely yours,

Secretary

RLZ:mk
Enc.

Lead Welding

Reprinted from
AWS WELDING HANDBOOK
Fourth Edition

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Lead Welding

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Lead

INTRODUCTION

Lead welding (burning*) is similar to the welding of other metals in that its purpose is to join two or more sections of metal into one continuous piece. The technique used to bring about this desired result, however, differs considerably from that employed with other metals. The major differences are that no flux is required in welding lead, and the size of the torch tip varies from drill sizes of 78 to 68.

The first successful attempt at welding was probably done on lead. This has been shown by samples of lead pipe dating back over 1800 years. The Romans of that era had complete water distribution systems, and most of the pipe used to convey water within cities and homes was made of lead. The pipe was manufactured in standard lengths and sizes, and the method of manufacture was a crude form of welding, as compared to today's methods.

GENERAL PROPERTIES

As a raw material, lead is marketed in pigs averaging 100 pounds. Pig lead is available in several grades, as specified in the ASTM Standard Specifications for Pig Lead B 29-55 (Table 71.1).

The various grades of lead find their principal uses in certain applications, but are not necessarily confined to these applications. For example, corroding

* Lead burning is the trade terminology very often used to describe lead welding.

lead, because of its high purity, is most extensively employed in the manufacture of white lead and other pigments. Chemical lead and acid-copper lead are widely used under corrosive conditions. Common desilverized lead is essentially used for general purposes.

Table 71.1—ASTM standard specifications for pig lead[a]

	Corroding Lead (b)	Chemical Lead (c)	Acid-Copper Lead (d)	Common Desilverized Lead (e)
Silver, max., per cent	0.0015	0.020	0.002	0.002
Silver, min., per cent		0.002	......	......
Copper, max., per cent	0.0015	0.080	0.080	0.0025
Copper, min., per cent	......	0.040	0.040	......
Silver and copper together, max., per cent	0.0025	......	......	......
Arsenic, antimony and tin together, max., per cent	0.002	0.002	0.002	[illegible]
Zinc, max., per cent	0.001	0.001	0.001	[illegible]
Iron, max., per cent	0.002	0.002	0.002	0.002
Bismuth, max., per cent	0.050	0.005	0.025	0.150
Lead (by difference), min., per cent	99.940	99.900	99.900	99.850

(a) ASTM B29-55
(b) Corroding lead is a designation that has been used in the trade for many years to describe lead which has been refined to a high degree of purity.
(c) Chemical lead is a designation that has been used in the trade to describe the undesilverized lead produced from Southeastern Missouri ores.
(d) Acid-copper lead is made by adding copper to fully refined lead.
(e) Common desilverized lead is a designation used to describe fully refined desilverized lead.

Lead is easily rolled into sheet or extruded into pipes, wire, cable sheathing or practically any desired cross section. It is easily worked, forged, cast, and alloyed with other metals. Two alloys commonly used in the industry are tellurium lead and antimonial lead. In both of these, the alloying elements impart certain characteristics to the lead. The addition of tellurium, less than 0.1%, improves the work-hardening capacity of the lead. The addition of antimony, usually about 6%, increases the hardness and provides about twice the tensile strength of soft lead at ordinary temperatures. However, antimony lowers the melting point markedly, to a degree which depends on the percentage added.

Lead melts at 621° F and boils at 3092° F. When freshly cut, its surface has a bright, silvery luster which oxidizes to a dull gray. Lead is resistant to corrosion from ordinary atmosphere, moisture and water, and is particularly effective against many acids, such as sulfuric and chromic.

In specifications, the thickness of sheet lead is usually referred to by weight in pounds per square foot. The thickness in inches can easily be ascertained by following, in general, the formula that one square foot of lead $^{1}/_{64}$ in. thick equals one pound. For example, 8-lb sheet lead weighs 8 lb per sq ft and is $^{8}/_{64}$ or $^{1}/_{8}$ in. thick.

Lead pipe is usually specified by inside diameter and weight per foot or by wall thickness.

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WELDING OF LEAD

Gas welding is most commonly used for welding lead. Other welding processes have been used on an experimental basis only.

Special Equipment

The following tools are needed for lead welding:

1. Torch tips ranging in drill size from about 78 to 68. The smaller tips are for use with 6-lb lead and lighter, and the larger tips for heavier lead. Depending upon conditions and the welder's experience, torch tips larger than 68 drill size are sometimes used. Light fingertip torches with control taps separate from but easily accessible to the welder are preferred.
2. Mallets and dressers of materials that will not dent or mar the lead for dressing the sections of lead to be joined so that they are suitably aligned for welding.
3. Wooden turn pins for expanding one end of a length of pipe so as to easily insert another section of pipe to form a cup or lap joint.
4. Shave hooks, scrapers and wire brushes for cleaning or removing oxide from the lead over the areas that are to become a part of the joint.
5. Various tools for cutting the lead uniformly.
6. Metal molds for use on vertical butt seams.

Fuel Gases

There are three combinations of fuel gases commonly used. They are oxyacetylene, oxynatural gas and oxyhydrogen. The oxyhydrogen and acetylene mixtures can be used for all-position welding. However, oxyhydrogen is preferred by most lead welders. The oxynatural gas mixture is satisfactory for the flat, horizontal and vertical positions.

Gas Pressure and Flame

A low gas pressure, which varies from 1 1/2 to 5 psi according to the type of weld to be made, is generally used. The flame must be a neutral one, as a reducing flame will deposit soot on the joint and an oxidizing flame coats the molten globules of lead with an oxide film which acts as a barrier between the molten globules and prevents coalescence. The length of the flame will vary, but it is usually somewhere between 1/2 and 4 inches, depending upon the pressure and volume of gas used.

Filler Metal

Filler metal is generally in the form of lead rods, varying in size from 1/8 to 3/8 in. in diameter. The smaller sizes are used for light-weight lead, and the larger sizes for heavier lead. The selection of rod size is usually a matter of the welder's preference. The filler metal should be of the same composition as the lead which is being welded. For example, if 6% antimonial lead is being welded, a 6% antimonial filler metal should be used.

Working Precautions

The sections of the lead that are to become a part of the joint should be scrupulously cleaned by shaving or wire brushing. This includes the inner surface of pipe joints which will be in contact as well as the exposed areas. On square butt joints, the abutting edges as well as the surface on which the reinforcement will be deposited should be cleaned. On lap joints, the edge and underside of the lapping sheet and the top of the lapped sheet extending beyond the lap to the edge of the area over which the weld will be deposited should be cleaned.

JOINT DESIGN

Sheet

There are three basic types of joints commonly used in welding sheet lead: butt, lap (Figs. 71.1–3) and flange. On flat work, the butt and lap types of joint can be used interchangeably, depending upon conditions of installation. On vertical and overhead work, the lap joint is almost always used. The flange joint, which is not illustrated, is used only under special conditions.

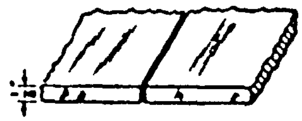

Fig. 71.1—Typical butt joint for sheet lead 1/8 in. thick or less

Pipe

The butt joint is usually preferred with the lap and cup joints as alternatives in lighter-weight lead, up to about 6/32 in. wall thickness. (See Figs. 71.4–6.) The flange joint is often used on larger diameter pipe, but differs from the flange joint used on sheet lead. The flange for pipe joints is cast or made from sheet lead and is then welded to the pipe.

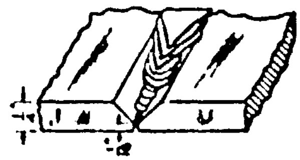

Fig. 71.2—Butt joint design for sheet lead over 1/8 in. thick

Joint Preparation

The lap joint is generally prepared by lapping the edge of one member over the other about 1/2 to 2 in., depending upon the thickness of the lead. The thicker the lead, the greater the lap. The underside, edge and top face of the upper member, as well as the top face of the lower member, which will all form part of the joint, are scraped clean. Band saws with special lead cutting blades may be used to cut sheet lead when preparing joints.

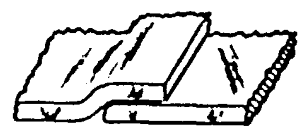

Fig. 71.3—Typical lap joint for use in joining sheet lead

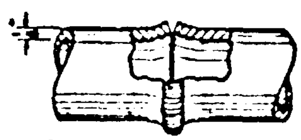

Fig. 71.4—Butt joint for pipe with 1/8 in. wall thickness or less

The butt joint is prepared by placing the edges of both members together. For material weighing less than 8 lb (1/8 in. thick), no beveling of the edges is necessary. However, for heavier weights, the edges should be beveled to an included angle of 45 to 90 deg., except for a root face of 1/16 in. minimum, usually without root opening. (See Fig. 71.2.) The root faces should be

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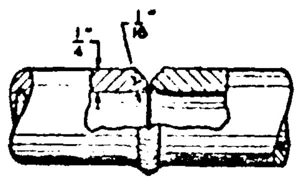

Fig. 71.5 - Butt joint for pipe over 1/4 in. wall thickness

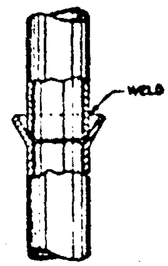

Fig. 71.6. - Cup joint for pipe in vertical fixed position

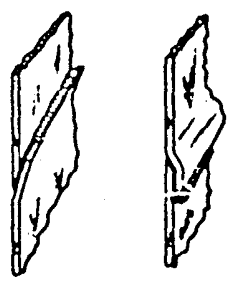

Fig. 71.7 -(left) Overhand technique for welding in the horizontal position (right) Underhand technique for welding in the horizontal position

shaved clean, as well as the top surfaces of the two parts over the area forming the joint.

The flange joint for use with 4-lb and lighter sheet is prepared by turning up to a right angle the ends of the sheets to be joined. Both facing sides and edges of the upturn should be scraped clean and then butted together.

TORCH MANIPULATION

Manipulation of the torch and the kind of flame used will depend upon the type of joint being made and the position of welding. In general, a semi-circular or V shaped motion is used. The molten lead is controlled and directed with the flame, thus accounting for the circular or herringbone appearance of the joint. Each semi-circle or vee is made in one continuous operation, the flame being flicked away from the work at its completion. (See Figs. 71.9 and 71.10.)

When welding in the horizontal position, a soft, bushy flame is most desirable. In the vertical and overhead positions, a more pointed flame is generally used. This will vary to some extent with the individual welder.

Welding Positions (Sheet Lead)

Flat Position

The butt joint is the most commonly used type for flat-position welding. For thin sheet, 1/32 to 1/16 in. (2 to 4 lb), flanges 1 to 1 1/2 times the sheet thickness may be bent up, cleaned and butted together. Lap joints are sometimes preferred, due to the simplicity of fitting. The welding torch is moved in a semicircular path toward the lap and then straight away from it. Filler metal is generally used, although not on the first pass. Flat welds are illustrated in Figs. 71.1–3 and 71.9.

Vertical Position

Lap joints are used almost exclusively when welding lead in the vertical position. Welding is begun at the bottom of the joint and the flame is applied to the lead at the junction of the front and rear sheets. When the edge of the front sheet becomes molten, the flame is carried with a circular downward motion back into the sheet, completely liquefying the overlap. Then the flame is carried almost horizontally over the underlapping sheet, fusing the front and rear sheets together. A filler rod is not generally used (Fig. 71.10).

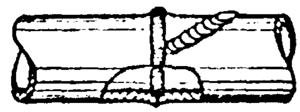

Fig. 71.8.—Technique for welding pipe in the horizontal fixed position

In rare instances, butt joints are used, but this would be more of a casting operation. In this type of operation, molds are held in place and the lead is melted into and fused with the joint by directing the flame into the mold.

Overhead Position

The overhead position is the most difficult of all for welding lead and is to be avoided wherever possible. However, if it is necessary to weld in this position, the lap joint is the most suitable type, and as sharp a flame as possible should be used. The weld beads should be small and the operation should be completed as quickly as possible. No filler rod is used. The pressure of the flame and capillary attraction are usually sufficient to hold the molten lead in place.

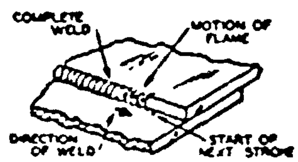

Fig. 71.9.—Technique for welding lap joint in the flat position

Horizontal Position on a Vertical Surface

There are two methods of making joints in the horizontal position. They are the overhand method, which is the easier method and therefore preferred, and the underhand method. Both produce lap-type joints. In the overhand method, the lower sheet to be joined is the overlapping sheet, and the edge of the lap is left slightly open. The flame is inserted into this opening and welding is done in what amounts to a flat position (Fig. 71.7 left.) The lap is not used as filler metal, but becomes part of the flare in which the welding is performed. Filler metal is supplied by a lead filler rod. The underhand method is necessary if the upper sheet laps over onto the lower sheet. The lap is dressed tightly against the lower sheet, and welding is performed by using the downside lap edge as filler metal. The flame is pointed at the lower sheet and

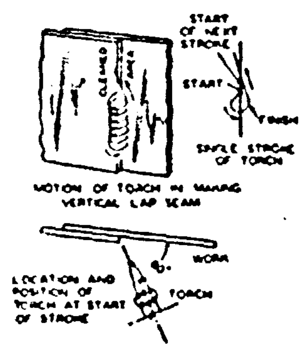

Fig. 71.10.—Technique of welding lap joint in vertical position

cut into the overlap when the bead is formed. No filler rod is used. The underhand joint (Fig. 71.8 right) is almost as difficult to complete as joints in the overhead position, and should be avoided if possible.

Welding Position (Lead Pipe)

For best results in welding pipe joints, the work should be planned so that as few joints as possible will have to be made in place. Where the pipe can be rotated horizontally, welding can be performed in a flat position.

Where rolling is impossible and the pipe is in a horizontal position, a butt joint is generally used. To avoid overhead welding, a vee section is usually cut in the upper part of one end of the abutting pipe. This allows access to the lower part of the joint, which is then welded from the inside of the pipe. The vee cut is then replaced and welded from the outside, as is the upper part of the joint (Fig. 71.8). An alternative method is to cut tee-slots in the upper part of both ends of the pipe, folding back the lead and following the same procedure as previously mentioned to complete the weld.

For pipe joints in the vertical fixed position, the cup joint should be used (Fig. 71.6). The lower section of pipe is flared out, and the upper section is beveled to fit into the flared end. The flame is directed into the flare and, using a lead filler rod, the two sections of pipe are welded together. Multiple passes are usually necessary. The welding procedure is similar to that used for a groove-welded butt joint.

Weld Size

From one to five layers of lead may be applied by welding, depending upon the thickness of the lead to be joined. In general, a weld reinforcement of about 1/4 in. is used for butt joints. In flat lap joints, the rule is to build to the thickness of the top sheet and then to apply one more pass. For vertical and overhead lap joints, multiple passes are seldom practical. For cup joints welded in the vertical fixed position, it is necessary to bring the weld even with the lip of the cup by means of multiple passes.

WELDING OF DISSIMILAR METALS

The welding of lead to other metals is generally confined to the application of a thick coating of lead to steel, copper or other metals to combine the corrosion resistance of lead with the structural strength of other metals. The resultant product is commercially referred to as "bonded lead" or "homogeneously lined lead."

Various methods of bonding lead to other metals are available to the fabricator. These include the application of the lead by hand and casting of lead onto the other metal. In any case, surface preparation of the metal to be covered is of paramount importance. In addition, pure lead does not readily wet other metals, and it is necessary to use special techniques or an alloy of lead, such as solder or antimonial lead, to coat the base metal prior to the application of the lead lining. Because steel is generally used as the base metal in bonded lead equipment, the procedures as applied to steel will be described in some detail. The same general techniques will be applicable to other metals.

Solder Coated Steel

Steel that is to be solder-coated should first be mechanically cleaned by application of grit, sandblasting or grinding, or chemically cleaned by pickling. In handling the steel after this step, extreme care should be taken to prevent oil or grease from coming in contact with the cleaned surface.

A corrosive flux, such as zinc chloride, is then applied, followed by application of a 50% tin, 50% lead solder. This is generally applied either with a torch or by dipping the steel into a molten bath. While still molten any excess solder is wiped off with a cloth. After the solder has solidified but while it is still hot, any remaining flux should be removed by wiping with a cloth that has been dipped in hot water.

Antimonial (Hard) Lead-Coated Steel

The procedure to be followed when coating steel with antimonial lead is exactly the same as that described for coating steel with solder, except that no flux is required and 6% antimonial lead is used in place of the 50-50 solder.

Lead Coating of Precoated Steel with a Torch

In applying a lead coating to precoated steel with a torch, the flame is directed on the steel coating until the coating is melted. The flame is then transferred to the lead filler metal rod, which is held close to the area being worked on. As the lead flows, the torch is transferred to the next overlapping area. No attempt should be made to lay down the required thickness of lead in one pass. Three passes are usually required to build up a thickness of 1/4 inch.

After the first pass, the lead should be carefully examined for pinholes and other faults. If any exist, they should be repaired by scraping down to the steel, reapplying the "tinned" coating and filling with lead. This first layer of lead may then be scraped down to a more uniform thickness, and the second pass applied. After each pass the surface should be examined for faults and repaired prior to continuing. When the specified thickness of lead is reached, the lead may be machined or scraped to a smooth, uniform surface.

Lead Coating of Uncoated Steel with a Torch

Steel which is to be coated with lead should first be mechanically or chemically cleaned as previously described. A flux of either zinc-ammonium chloride or stannous chloride is then applied to the working area just before the coating operation. The flame is played on the steel and on the lead filler material. Care should be taken that the flux is not destroyed by the heat before the lead starts to flow. Subsequent procedures are the same as those described in the section entitled "Lead Coating of Precoated Steel with the Torch."

Lead Coating by Casting Methods

In this method of coating, the steel is prepared by mechanically cleaning or pickling the surface to be lined. The surface is then fluxed with zinc-ammonium chloride or stannous chloride, and heat is applied, generally on the underside of the sheet. Lead filler material is then rubbed vigorously on the treated steel surface until a thin coating of lead adheres to the steel. Molten lead is then cast on this surface to approximately twice the desired thickness. Any insoluble impurities such as dross present in the lining will float to the surface. After the lead has cooled, this excess coating containing the impurities is removed by scraping to the specified thickness.

The roughened surface is then smoothed by flame washing, which also serves to repair any minor defects.

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WELDING SPEED

The speed of welding butt joints in the flat position is not very different from the speed developed when gas welding steel. Speeds of 30 ft per hr are common with 8-lb sheet lead. Granjon's formula for determining welding speed is:

$$V = \frac{1.92 \text{ to } 3.85}{T}$$

where:

T = lead thicknesses, inches
V = burning speed, ft/hr

Filler Metal Consumption

On butt joints, a rule of thumb for filler metal consumption for a single pass weld is: one foot of rod to one foot of joint, where $^1/_4$-in. dia. rod and 8-lb lead are employed. One pound of $^1/_4$-in. dia. filler rod will supply approximately four feet of weld.

SUPPORTS FOR SHEET LEAD LINED TANKS

Where high temperatures are used within a loose lead-lined tank or rapid cycles of heating and cooling are encountered, or where the depth of the tank is more than eight feet, reinforcement of the lead lining is necessary. This reinforcement is generally provided by vertical steel strapping, or by the so-called "button" type of fastening. All reinforcing methods are applied after the lead lining is installed.

Vertical steel strapping is accomplished by welding studs on the steel lining through pre-cut holes in the lead or with preplaced bolts in the steel or wood tank. Half-oval steel straps are placed over the threaded studs or bolts and drawn up tightly. A lead strip of the same weight and composition as the lead lining itself is then placed over the steel strap and welded securely on each side to protect the steel strapping from corrosion. Good vertical strapping practice is to place the straps about 18 in. apart; they should never be more than 24 in. apart. Studs and bolts are generally placed on 18-in. centers. 12-in. centers are occasionally used, but the centers are never more than 24 inches.

With the "button" type of fastening, a large steel washer and a roundhead bolt are used on steel and wood tanks. The bolts are evenly spaced over the entire lead lining at about 18-in. centers. After the bolt is drawn up tightly, a lead cap completely encircling the steel washer and bolt head is welded to the lead lining.

Where exceptionally severe conditions prevail, particularly when abrasion or erosion is a factor, where the vessel operates under high pressure or a vacuum, or where acids and alkalies must be handled in the same vessel, an acid-brick lining on top of the lead lining is recommended.

SAFETY PRECAUTIONS

Because of the toxic nature of lead, lead welding should be performed in well-ventilated locations to prevent inhalation of excessive amounts of lead fumes or dust. Men working in confined areas, such as the bottom of a deep, open tank, should be provided with a positive air supply directed into the tank by a fan or blower to a position below the breathing level. In enclosed areas such as

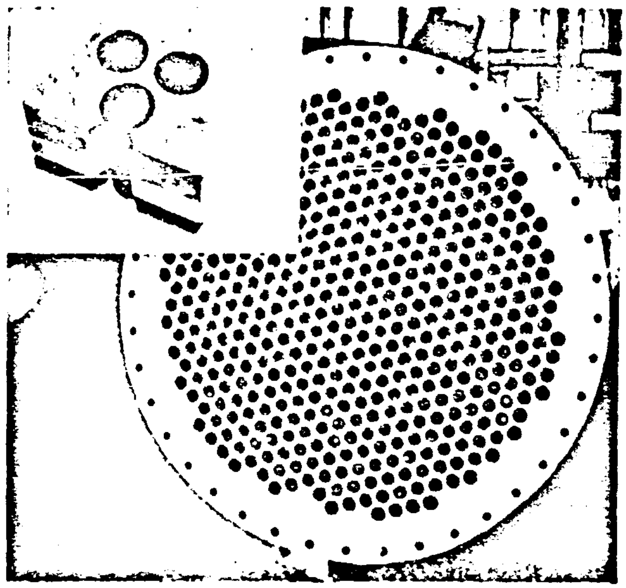

Fig. 71.11 - Lead bonded steel tubesheet for use in a phosphoric acid evaporator

pressure vessels or closed tanks, each man should be required to wear an air-supplied respirator or mask. (See Chapter 11, Section 1, for more detailed information.)

COMMON APPLICATIONS

The widespread use of lead in the chemical industries is a direct result of the ease with which it can be joined by welding, as well as its exceptional resistance to corrosion by a wide variety of chemicals.

Lead welding is used in lining tanks, in conveyors, and in other equipment used to store or mix chemical solutions. For example, it is used to produce such equipment as heat exchangers in a phosphoric acid evaporator (Fig. 71.11), an oxidation autoclave in a cobalt refinery, for manufacturing sulfuric acid by the chamber and contact processes, electrostatic precipitators, table tops and piping for chemical laboratories, acid-resistant floors in chemical plants (Fig. 71.12), and numerous other equipment used in the chemical processing industries. Lead welding has been used extensively in the preparation of lead-shielded components for gamma ray attenuation. This is particularly true of mobile

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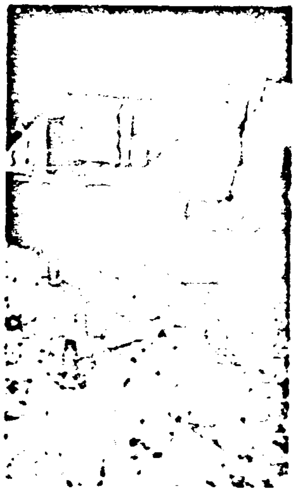

Fig. 12 - Welding of an upstand around an opening in a steel lead lined floor. Lead sleeves around pipes are also welded to the floor.

power reactor equipment such as that used on naval and merchant ships.

The Atomic Energy Commission has stated: "Where large attenuations of gamma-radiation intensities are desired, the use of lead instead of iron results in a weight saving of 30 percent. . . . It is often important that the lead be bonded properly to structural supports by lead welding and that no void exists between the lead and structural members." *

Lead welding has been used extensively in the installation of nuclear power plants in submarines. The lead may be in the form of cast slabs, sheet lead or lead-bonded steel.

Cast slabs are first positioned and secured to the steel by edge bonding. The areas of the steel where this edge bonding is performed are first cleaned and then tinned with solder, using a zinc chloride flux. The areas between adjoining cast lead slabs or between the lead and the structural steel are also filled by overlaying lead to the required thickness.

When sheet lead is used to make up the required thickness, each sheet is edge bonded to the steel structure and to the lead sheet beneath it. Gaps between adjoining sheets or the steel structure are filled by overlaying with lead.

Where lead bonded steel is used, the steel backing plate is welded to the steel structure and the lead edge is bonded to the structure. Any gaps are filled as previously described.

* "Reactor Shielding Design Manual," Atomic Energy Commission.

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