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See Chemical Bulletin No. 47

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[illegible] CHEMICAL CONSTRUCTION
[illegible]

SUBJECT: LEAD IN [illegible]
CHEMICAL CONSTRUCTION

Attached to this letter is a reprint from the January, 1952 issue of "Chemical Engineering" magazine entitled "Lead in Modern Chemical Construction." The article describes what should be known about various types of lead construction in modern chemical engineering.

As long as our supply lasts, we will be pleased to send you additional copies for distribution to those whom you feel may benefit. As similar material becomes available, we will send it on to you so that it may be added to the series.

Very truly yours,

Robert L. Ziegfeld

Robert L. Ziegfeld
Secretary.

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Lead in Modern Chemical Construction

What you should know about the various types of lead construction, if you use lead in your processing or have plans for doing so.

KENSTON H. BULL

The [illegible] techniques and improvements [illegible] the test of [illegible] in the [illegible] making [illegible] of [illegible] lead [illegible] lead [illegible] to as [illegible] or [illegible] (Fig. 2), lead covered copper or steel heating coils, and the use of acidproof brick with an impervious lead interliner.

SHEET LEAD CONSTRUCTION

Lead in the form of sheet supported in a steel or wooden framework, or a steel or wooden shell lined with sheet lead are the two principal methods of sheet lead construction. The latest developments in both methods, generally termed cage construction and lead lined construction, are described in detail below. Actually there are probably as many modifications as there are applications for both types of construction, for they are the oldest methods of using lead as a material of construction. But despite their antiquity, they still represent the major part of all the lead used by industry for handling corrosives.

Sheet lead construction is ideal for the storage of corrosive chemicals and is generally regarded as the method which requires the least capital outlay. Should repairs be necessary they are easily effected in the field and once the vessel's useful service life has expired, the lead may be reclaimed as scrap and sold at the highest relative rate of any of the common metals. Sheet lead can easily be assembled and welded in the field with the aid of only a lead burning torch. Tanks of great variety both as to design and usage—pickling, chromium and copper plating, anodizing, acid storage, manufacture of a wide variety of chemicals—are among the common applications of sheet lead linings.

CAGE CONSTRUCTION

The first chambers for the manufacture of sulphuric acid were of cage construction, simply large sheet lead boxes supported by timbers. Acid chambers [illegible] lead [illegible] framework [illegible] more [illegible] A [illegible] system for [illegible] at the same [illegible] of [illegible] (Fig. 2).

The [illegible] is by no [illegible] still not [illegible] many potential users. In place of [illegible] a steel or wooden shell lined with sheet lead, a basket or cage-like structure made of steel flats and angles welded together to form an open framework is used for supporting the lead. Depending upon the height of the vessel, the straps are often placed closer together at the bottom than at the top to give extra support where hydrostatic pressure is greatest.

This type of open construction in which the lead is fully exposed to the atmosphere provides an extremely effective and inexpensive method for cooling liquids which are received hot or where heat is generated by reaction such as in acid dilution. Heat is dissipated rapidly to the atmosphere by air convection and radiation.

Cage construction offers several other advantages over solid steel tanks as long as high pressure or vacuum is not encountered. The spacing between the straps permits a leak to be seen immediately. Furthermore, it can be repaired from the outside in a matter of minutes. If the size of the vessel calls for extra support, internal strapping which of necessity must pierce the lead lining in order to be fastened can be eliminated by using the cage-type construction. Instead strips of lead can be burned from the outside over the horizontal steel straps and thus support the lead.

Other advantages of cage construction are lower material costs and often easier assembly in the field, the handling of bulky and heavy steel sheets being eliminated.

LEAD LINED CONSTRUCTION

Sheet lead lined wooden or mild steel tanks are in common usage and have been for many years. Storage vessels for corrosives, nickel, chromium and copper plating tanks, anodizing tanks, tanks for electrolytic refining of lead, zinc and copper, chemical reaction vessels, pickling tanks are all common examples of equipment lined with sheet lead. Lining thicknesses usually range between 8 and 16-lb., although two or more different thicknesses may used in the same vessel [illegible] to [illegible] required. [illegible] or [illegible] constructed [illegible] wood or steel can be [illegible] lined with lead to make them suitable for handling corrosives. In other words, by lining any old but structurally sound vessel with lead, it becomes unnecessary to construct an entirely new one, thus eliminating the extra costs of labor and materials.

In small storage vessels the lining is hung from the top without any strapping. More often it is provided with additional support by any of the means described below. Generally in the form of strapping, extra support is resorted to when fluctuating temperatures, fatigue or stress corrosion must be considered. In deep tanks, because of the high density of lead (0.410 lb. per cu. in.), loose linings must be strapped to overcome the effect of gravity. In practice, the optimum height of a loose lead lined vessel without benefit of any support from strapping rarely exceeds 10 ft., depending upon the weight of lead. Good vertical strapping practice is to place the straps about 18 in. apart and no more than 24 in.

Fastening the straps used to support loose sheet lead linings has been simplified by a recent innovation making use of automatic stud welding. A threaded stud can now be butt welded directly to the inside of the shell with a special gun into which the stud is loaded. A press of the gun's trigger applies welding current for a preset amount of time. The stud has a small recess at its end which contains the flux necessary for welding. A ceramic ferrule over the end of the stud confines the arc to a limited space, giving a shielded-arc effect. Portable motor-generator sets or battery-powered units provide current for the arc.

The stud may be welded directly through precut holes in the lead or between two lead sheets where they butt together. Half-oval steel strapping is slipped over the threaded stud and on top of the lead. The top of the strap is recessed to receive the fastening nut (see cut). After bolting the strap, a lead strip is placed

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over the steel and welded securely on each side to protect the steel from corrosion. Studs are usually placed on 18-in. centers, occasionally 12 in., but never more than 24 in.

Often it is advantageous to use a large steel cut washer and a roundhead bolt to fasten sheet lead to a steel or wooden shell. The bolt and washer are covered with a lead cap which is burned to the lining. This tends to distribute the lead over a large area and thus aids in minimizing fatigue. The bolts used in this manner are evenly spaced over the entire lining at about 18-in. centers.

Sheet lead for lining all types, shapes and sizes of chemical equipment usually comes in rolls ranging from 8 to 12 ft. wide and up to 60 ft. long, depending upon the thickness of the sheet. A standard roll is generally 20 ft. Thickness varies from 1/80 in. to 2 in., or measured in the parlance peculiar to the lead industry —1 lb. to 120-lb. (lead 1/64 in. thick weighs about 1 lb. per sq. ft. and is designated 1-lb.). In chemical construction lead weighing less than 8-lb. is rarely encountered.

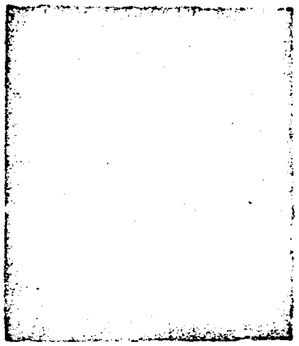
TESTING OF LEAD LININGS AND WELDS

A non-destructive method of testing lead linings and welds requiring no electrical equipment and involving only the expense of the chemicals used was recently placed on the market. The new process is used for inspecting the surface of metals and detecting any openings such as cracks, laps, cold shuts and porosity. Discontinuities are indicated by bright red lines, dots or blotches on a white background.

The process involves the use of three liquids, penetrant, developer and cleaner, which may be sprayed, brushed or dipped on the surface to be inspected. First the surface is cleaned, then covered with the penetrant which is left on for 5 or 6 min. A gallon of penetrant will cover an area of approximately 3,000 sq. ft. After removing the penetrant with the cleaner, the developer is applied. The red penetrant will remain in any crevices until it is drawn to the surface by the action of the white developer. A red line or blotch indicates a crack or cold shut; a series of red dots in a line indicates a tight crack, cold shut or partially welded lap. Tiny hairline cracks which appear when lead has been overstressed, particularly under corrosive conditions, may be detected by the above-mentioned method.

Bonded lead linings described below may be tested by either the above method or by this one: brush on a

Lead-Lined Construction



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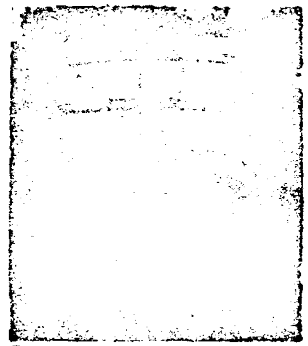
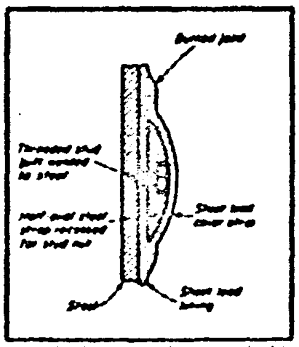
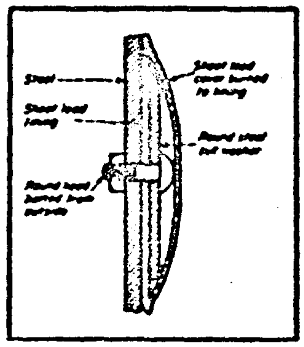


Cup-type construction





Methods of supporting loose sheet lead linings

solution of 50 percent hydrochloric acid and allow to stand for 24 hr. The presence of pinholes will be indicated by rusty discoloration. After marking such spots the entire surface is washed with water and repairs made where required.

Another leak detection method that has also been used on lead is based upon a fluorescent penetrant instead of a colored dye penetrant. Surface discontinuities are indicated by this method in much the same manner as by the dye penetrant method described above. A fluorescent penetrant is applied by brushing or spraying and then removed by a water wash, after 5 to 15 min. Developing powder brings out the penetrant and observation under a "black light" reveals any discontinuities.

BRICK AND LEAD LININGS

The handling of corrosive slurries and other combinations which both corrode and erode most materials of construction have led to the development and practical acceptance of brick and lead lining, i.e., a steel shell lined with lead, with or without a layer of asbestos sheeting followed by a layer or two of acidproof brick set in suitable acidproof cement.

Brick and lead lined vessels are recommended particularly where any of the following conditions prevail: (1) abrasion or erosion is a factor, (2) severe corrosive conditions are encountered (for example, where acids and alkalis must be handled in the same vessel), and (3) thermal shock—rapid and high temperature fluctuation.

Brick linings alone are always somewhat permeable due to the inherent porosity of the brick and the inability of the bricklayer to secure a continuous film of cement between and in back of the brick. No cemented conglomerate can be as impervious to liquids as can a metal. In fact, the best grades of acid-proof brick are intentionally made 3 to 4 percent porous in order to provide optimum thermal shock resistance. A lead lining acts as an impervious barrier between the shell and the brick so that any corrosive seepage through the brick lining is retained by the lead, thus preventing damage to the steel shell. The lead and brick linings are then complementary to each other and serve as a particularly effective type of construction.

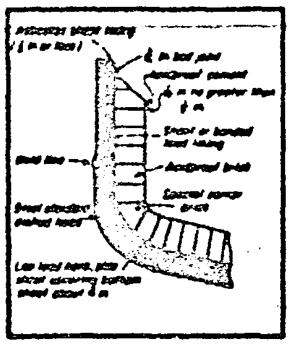
APPLICATION

In building a brick and lead lined steel tank, the tank should be built to support the weight of the entire structure. Neither the lead nor the brick can be assumed to contribute any structural strength to the vessel. Bottoms should be dished where pressure is involved and the walls preformed at or above the bottom edge (see drawing).

A lead lining is applied next after removing all burrs or other projections on the inside of the tank which might cause injury to the lead. Chemical grade 8 or 10-lb. lead (⅛ or 3/16 in. thick) is usually adequate and has found most application. It should be lapped over the top edge of the vessel to prevent seepage between the lining and the steel, the side sheet extending down about 4 in. over the top of the bottom sheet. They should be welded together around the entire exposed edge. In very large vessels or at high operating temperatures, it is advisable to strap the lead to the shell. Under severe operating conditions bonded lead linings are employed, in which case lead of greater thickness is generally used. Because the initial cost is essentially that of the bonding operation, using thicker lead adds little proportionately to the total expense involved—but it does make for increased service life.

After installation, the lead lining should be tested for leaks in the manner described in the section above on testing of lead linings and welds. After the lead has been installed and tested, a layer of asbestos sheeting or some similar material 1/16 to ⅛ in. thick is added to act as a cushion between the brick and the lead protecting the lead against abrasion during expansion and contraction.

Finally, the vessel is lined with one or two courses of brick, the brick selection depending upon several factors: the degree of acid insolubility required, minimum allowable porosity and the degree of thermal shock involved. The thickness of the brick is determined by the dimensions of the vessel, the amount of mechanical abuse anticipated and the thermal insulation required. Brick size is commonly 9 in. x 4½ in. x 2½ in.,



Bottoms of brick and lead lined tanks are dished where pressure is involved.

though other sizes and special shapes are available.

Brick in two courses is laid so that the wall and the floor courses can be keyed in and joined with a minimum of cement, usually a 1/16 in. layer and no greater than 3/16 in. The bed joint (between the brick and asbestos or lead) is about ¼ in. thick. Classes of cements are considered on the basis of desired corrosion resistance, temperature, erosion and porosity, plus the economics of cement and installation costs. Acidproof cements available on the market include silicate cements, sulphur cements, phenolics, furfural alcohol resin base cements and modified phenolic resin base cements. Litharge-glycerin cement (80 to 100 cc. of glycerin per lb. of litharge) is occasionally used, particularly in the paper making industry where its excellent resistance to sulphurous acid liquors is utilized. It has good water resistance, withstands attack by nonoxidizing acids, and may be used safely up to 350 deg. F.

BONDED LEAD LININGS

A bonded lead lining in effect combines the corrosion resistance of lead with the strength of steel. Bonded lead is simply a layer of lead bonded to a steel plate so as to form a homogeneous or integral metallic structure. The thickness of the layer, depending upon the ultimate use, ranges from ⅛ in. to 1 in., with ⅛ in. to ½ in. being most common. By literally anchoring the lead to steel at all points of contact, relative movement between the two metals is minimized.

Bonded lead lined vessels are recommended for use where any of the following conditions prevail: (1) fluctuating temperatures are encountered, (2) high temperatures, (3) the vessel operates under vacuum, (4) vibration or physical shock are encountered, and (5) heat transfer is important such as in jacketed vessels (No insulating layer of air exists between the shell and the lining).

APPLICATION

The advantages of bonding lead to steel have been known for many years, but the development of efficient and less expensive methods for accomplishing this have, until recently, been lacking. Two methods that have been put into commercial practice for manufacturing bonded lead linings on steel are described below.

The first step in bonding is preparation of the steel prior to bonding. The usual procedure is to clean it first by shot blasting so that an uniform surface will be exposed. This may be followed by pickling, usually in a 10 percent solution of sulphuric acid, and rinsing with water. If the bonding is done immediately after shot blasting, no pickling is required.

The steel is now ready for fluxing. Flux should be applied to the working area where the bonding is to commence and immediately prior to the bonding operation. Zinc-ammonium chloride and stannous chloride are two fluxes commonly used, in addition to several proprietary fluxes for which certain advantages are claimed.

Here are the two common methods of bonding lead to steel:

Burning Bar Method—Probably one of the earliest methods of bonding lead to steel and one which is still in use today is the burning bar method. It begins with preparation of the steel in the manner described above either as a unit or in sections. Then lead is melted from a burning bar onto the prepared steel surface by using a hand operated lead burning torch.

This procedure is used to advantage in bonding small areas and irregular shapes. After building up the lead layer to slightly more than the thickness desired, the lead is peened, scraped, or its surface otherwise made uniform.

Pouring Method—Improvements in methods of pouring lead on steel have made this method of bonded lead manufacture an efficient and also less expensive one. The method consists first of preparing the steel surface usually in the form of a large plate by the methods described above. Molten lead is then carefully poured on the heated steel surface. After solidification, the steel with the bonded lead lining is often rolled in a conventional rolling mill to compress the lead and curve it to shape. On heavy curved sections or irregular castings, the lead is cast in overlapping sections by partially rotating the vessel after each pouring. In either case, the lining is

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then removed with special tools until a uniform thickness is obtained. Peening may or may not precede the scraping.

A new method has been successfully adopted for testing bonded lead linings to detect the presence of unbonded areas. The completely bonded vessel is sealed and heated internally by means of an appropriate hot air blower system so as to raise the temperature of the shell to about 400 deg. F.

If any non-bonded areas are present, a small amount of air trapped in this area expands and causes a conspicuous bulge in the lead. It is a simple matter, after cooling, to inspect the vessel for the presence of bubbles and re-bond these areas by hand.

LEAD PIPING AND COILS

Lead is readily extruded into a variety of shapes and sizes and large quantities of extruded lead are used in the plating, chemical and related industries principally as pipe for conducting corrosive solutions and as cooling or heating coils submerged in corrosives. Sizes are limited only by the extrusion equipment available and may include wall thicknesses of any size and cross-sections of practically any shape. The largest commercial lead extrusion currently made is 12 in. inside diameter.

Joints in lead pipe may be of the Van Stone type made by butting together flanged sections and securing them with two bolted cast iron or steel slip-on flanges. They may also be butted together and welded. In the case of vertical pipe, sections are joined with a "cup" joint. In this type joint, the lower section of pipe is flared out and the upper beveled to fit into the flared end where it can be welded.

Lead pipe coils have found widest acceptance for cooling purposes, chiefly because of lead's corrosion resistance and the ease with which it can be formed. Lead coils usually are helical in shape but may take other forms and are constructed of extruded lead pipe. Flat coils for the ends and bottoms of the tanks are also used. Pipe extruded with a fluted or ribbed cross-section for greater surface area is commercially available.

One of the latest lead coil developments is a heat exchanger consisting of two lead pipes, one within the other. The larger pipe has an inside diameter of 2 in. with ⅛ in. wall and is extruded from 6 percent antimonial lead. The inside pipe made of soft lead is 1 in. diam. with a ⅛ in. wall at the thin portion. The exterior of the inner pipe has been extruded in the shape of a six-pointed star to provide extra support and also to retain concentricity. The pipes were designed so that the area of the space between the two is approximately equal to the cross-sectional area of the inner pipe. After extrusion the coil was assembled by inserting the smaller pipe into the larger and coiling both into units 11 ft. in circumference and 27 coils high. The unit performs the dual function of cooling a solution circulating between the two pipes and heating another solution circulating through the inside pipe.

Because of lead's weight, it is frequently advisable to support it over long spans either with strap hangers or by laying it in steel channels or by using lead lined pipe. Steel or iron pipes lined with lead are used to advantage when pressures exceed 50 lb. steam (298 deg. F.) or the expense of supporting the pipe by other means is disproportionate. Lead lined pipe is commercially available from 1 in. to 12 in. in diameter, the lead lining thickness ranging from ⅛ in. to ⅜ in.

BONDED LEAD AND LEAD COVERED PIPE

Bonding techniques similar to those described above have been utilized in the manufacture of lead lined steel pipe and lead covered copper pipe. In all cases the purpose is the same: to utilize lead's corrosion resistance in combination with the strength of steel or copper. In making bonded lead pipe a length of steel is first cleaned and fluxed. Then molten lead is cast on in sections by rotating the pipe. A second method uses instead of molten lead, a length of extruded lead pipe which is inserted inside a properly prepared pipe of steel. The ends of the lead pipe are sealed and steam pressure applied to expand it against the outer pipe. Pressure is raised until the temperature reaches the point where bonding takes place between the lead and steel, aided by pre-tinning the steel with a thin solder film.

Solder bonded lead lined steel pipe is recommended when design or operating conditions involve temperatures up to 250 deg. F. vacuum, high pressure, vibration or physical shock and, of course, the handling of corrosive chemicals. Pipe sizes range from ½ in. I.D. to 12 in. I.D. with lead lining thickness either ⅛ in., ³⁄₁₆ in. or ¼ in.

Lead covered copper and steel pipe is made somewhat like bonded lead lined pipe except that the lead layer is on the outside instead of the inside. The pipe in length of about 10 ft. is cleaned and fluxed and mounted centrally in a circular split mold. Molten lead is poured around the pipe until it is completely covered. The pipe is finished by drawing it through a drawbench to bring the lead down to the thickness desired. By other techniques, continuous lengths up to 100 ft. can be made.

Lead covered copper coils can be operated up to 150-lb. steam pressure, while ordinary lead steam coils can operate successfully only up to 50-lb. steam pressure. This is the reason why lead covered copper has found such wide acceptance for use as heating coils. Copper absorbs and transfers heat with the greatest efficiency of the common metals and because lead is bonded directly to the copper with no air interface, heat transfer in lead covered copper pipe is maintained at its highest value. Because the physical strength to withstand high steam pressures is provided by the copper, it is practical to keep the thickness of lead covering at a minimum, thus the combined thickness of copper and lead is materially less than the wall thickness of lead pipe for the same application.

Formula for calculating the theoretical over-all coefficient of heat transfer for bonded lead covered copper:

$$U = \frac{1}{\frac{X}{K} + \frac{1}{h_s} + \frac{1}{h_l} + \frac{Y}{K_c}}$$

Where:

U = theoretical over-all coefficient heat transfer coefficient, Btu./hr./sq. ft./°F., K = conductivity of lead wall per in. (use 240), K_c = conductivity of copper wall per in. (use 2680), X = thickness of lead wall in inches, Y = thickness of copper wall in inches, h_s = steam film (use 1,000), h_l = liquid film (use 300).

Formula for calculating the area of heat transfer surfaces for bonded lead covered copper:

$$A = \frac{H}{U \times \Delta T}$$

Where: A = area of heat transfer surface in sq. ft., H = total heat load, Btu. per hr., U = overall rate of heat transfer, Btu./hr./sq. ft./deg. F., ΔT = mean temperature difference between the hot and cold fluids, in deg. F.

For heating coils:

$$\Delta T = \text{Steam temp. (°F.)} - \left(\frac{\text{starting} + \text{finished temp. of sol.}}{2}\right)$$

For cooling coils:

$$\Delta T = \left(\frac{\text{starting} + \text{finished temp. of sol.}}{2}\right) - \text{Cooling water temp.}$$

Lead bonded steel coil support legs are commercially available to eliminate the sagging of cast lead legs after prolonged operation at elevated temperatures. —End