LIA10112

LEAD INDUSTRIES ASSOCIATION

60 EAST 42ND STREET
NEW YORK 17, N.Y.

May 27, 1958

LEAD CHEMICAL CONSTRUCTION
BULLETIN NO. 20

SUBJECT: USE LEAD TO CONTROL
REFINERY CORROSION

Attached is a reprinted article "Use Lead to Control Refinery Corrosion," prepared by E. J. Mullarkey, Technical Director of the Lead Industries Association, which appeared in the April, 1958 issue of "Petroleum Refiner."

The article relates the latest practices in lead construction that explain how to get the best results with lead-lined equipment.

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Use Lead to Control Refinery Corrosion

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60 East 42nd Street
NEW YORK 17, N. Y.

Reprinted from *Petroleum Refiner* April, [illegible]

Use Lead to Control Refinery Corrosion

Here are the latest practices in lead construction that explain how to avoid the difficulties sometimes experienced with lead-lined equipment.

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PETROLEUM REFINERS rank high in the line of important sulfuric acid users. Over the past five years, over 40 percent growth in usage has been noted in the catalytic phases, for cracking and for alkylation. In addition to increased requirements for acid treating, this growth in acid consumption over the years has presented a continuing need for improved techniques in the use of lead chemical construction. In the areas of acid-production, containment of weak acid and acid sludges, and acid-reclamation, largely the consequences of the above-mentioned processes, few contest lead's important role.

Although by far the largest job for lead in oil refining, sulfuric acid handling is not alone in its demands. Perhaps not as large a use but definitely an important one is in the storage of alum solutions used for fire fighting. Lead's major uses do not end here, however, and it is not illogical that it is found in alum digestors and in production and containment of acid-alum solutions used in thermofor catalytic cracking. The latter use, in the reactor stage constitutes one of the severest tests of lead's applicability to date.

It is the purpose of this article to bring up-to-date the latest practices related to lead chemical construction because mechanical troubles are responsible for the greater part of such difficulties as are experienced with lead lined equipment. Knowledge of the corrosives encountered and their behavior with lead are also important. A typical case history commentary also adds to the useful knowledge of lead's employment in mitigating corrosion in this still growing market.

Before touching upon lead construction practices, comment on the corrosion resistance of lead is in order. When sulfuric acid and alum are used in combination, each reactant may be considered to act independently. Lead is highly resistant to corrosion by sulfuric acid at practically all temperatures and concentrations, although somewhat more corroded by very dilute or very concentrated acids.

Frequently mis-stated in the literature is the fact that the rate of corrosion of lead in contact with sulfuric acid increases rapidly in the very low concentration range (0 to 5 percent). For example, at 2 percent, the rate is roughly twice that at 5 percent and may indicate premature failure.

In this connection, it appears that at low acid concentrations antimony-bearing lead alloy passivation can be attributed also to a sulfate of antimony.

In the case of lead linings, it would appear that with all else being equal, antimonial lead should be recommended in preference to chemical lead for improved service in the very low concentration area with optimum corrosion resistance expected at 3 percent Sb.

In the case of alum $Al_2(SO_4)_3$, lead is quite resistant to corrosion at the lower concentrations and normal temperatures, and at higher concentrations and temperatures as well. Such failures of lead as do occur in contact with these solutions are not generally the result of corrosion but rather mechanical failures due to improper design and installation, and accentuate the fact that methods of construction are particularly important in the case of lead.

New developments in lead construction over the past five years may be considered to comprise new innovations of established methods and what may be considered the current thinking on what comprises best practice. Accordingly, where different from that previously published or where worthy of repeated mention, a general treatment of each of the methods for installing lead for corrosives' service are given which contain information descriptive of the conditions which warrant selection of a particular method and procedures for implementing that method. In addition pertinent test methods are described.

Bonded Lead Linings. To obtain the greater efficiencies afforded in some cases by high operating temperatures and vacuum, bonded lead linings have been perfected and used with success for a great many years. The combined properties of steel and lead are used to advantage under any of the following conditions or combinations thereof with the thickness of the lead layer being dependent upon the ultimate use:

- Operation of vessels under vacuum.
- Rapid fluctuation in temperature which may make loose lead linings unsuitable because of fatigue.
- Conditions where heat transfer is important (absence of air gap).
- Where weight of brick lead lining cannot be supported (elevated or very tall vessels).
- High temperatures which would produce excessive creep in loose lead

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linings. (Bonded lead linings will not creep or crawl up to 232C. (450F.)) and where

- Vibration or repeated shock are encountered.

To accomplish fabrication of a bonded lead-lined vessel, in what constitutes an improvement over previously published methods consisting of burning bar and casting methods separately,[3] the more recent practices[4] combine gamma-ray inspection with the fabricating sequence to the extent that fabricators can produce defect-free homogeneously bonded lead linings at only a small increase in construction cost.

Fabrication. Initially the plates to be bonded are pickled on the lining side, presumably with a 30 percent solution of sulfuric acid, suitably fluxed (zinc-ammonium chloride and stannous chloride are two fluxes commonly used[5]) and heated on a furnace. Application of the "first coat" is made by rubbing a burning-bar on the treated steel and after coating the surface in this manner, molten lead is added until twice the finished thickness is obtained. The double thickness serves to float impurities with the excess, containing this matter, being disposed of by chipping after the lead-steel assembly is allowed to cool. The resultant roughened surface is subsequently smoothed by flame washing, an operation which serves to check for, remove, and repair minor defects. Peening follows, which results in a more dense and reduced grain structure.

At this stage of fabrication and before the lead-bonded steel is rolled to vessel diameter gamma ray inspection is used. Normal exposure techniques are utilized with proper allowances for the lead thickness in exposure time. All radiographs are made with a 100-mc cobalt-60 source with fine-grained high speed film, and source to film distance held at 12 inches for exposures on plate steel. After the lead lined sheets are rolled and welded together, a 2½-inch strip on either side of the weld is lead bond by hand burning. This area is also inspected by radiography. Attachments are lined, welded to the vessel and finished off in a manner which is in accordance with general practice. The attachments are also radiographed with the source placed on the nozzle center line. The short distances involved result in maximum exposure times of 2 hours and in all cases the requirement of 2 percent sensitivity is met.

In interpreting films, very dark sharp markings indicate pinholes, gas pockets, or inclusions. Uniform general shading may be due to variations in lead thickness but if it begins or ends in a sharp line it warrants investigation. Dendritic or featherlike markings indicate the presence of slag or dross which should be removed. However, the latter markings are also indicative of an imperfect bond between lead and steel.

Radiography is carried out on a random or statistical sample basis with respect to the shell and heads. The nozzle necks are all radiographed 100 percent. Over-all cost of using this inspection method was found to be 5½ percent of the vessel fabrication cost. For 100 percent inspection, 10 percent of the vessel cost is estimated. In both cases, the added cost is small in terms of reduced downtime.

Other test methods which are not necessarily a part of the fabrication sequence include the "acid wash test" which is generally used to detect pinholing or porosity, ultrasonics relying on either resonance or pulse methods which are tests for bond discontinuity and for best results are conducted from the steel side only, and another method limited to pressure vessels.[6] The latter involves raising the internal temperature of the vessel by steam or other means to about 500F., cooling as rapidly as possible and examination of the lead surfaces for bubbles or raising which would indicate a lack of bond.

In service, testing and repairs usually involve visual detection of a [illegible] followed by removal of lead [illegible] the affected area, building up of the damaged steel shell with weld metal, and homogeneous bonding of lead over the repair area. A test for tightness usually follows and is done simply by filling the tank with water and checking for leakage. Ultrasonics may also be used to advantage to determine the thickness of the shell at any point during service and before visual leakages occur.

Sheet Lead Linings. Sheet lead linings usually involve the lowest construction costs, mostly because they can be formed and joined in the field with a minimum of equipment and man hour expenditures. Lowest costs are realized when the sheet lead is hung from the top of a vessel shell but this is not always possible design-wise and other innovations are used. These comprise strapping and several methods of fastening. However, in practice, the optimum height of a loose-lead-lined vessel without the benefit of strapping rarely exceeds 8 feet, depending on the weight of lead. In what is considered good vertical strapping practice, straps are placed about 18 inches apart and generally no more than 24 inches and subsequently covered with sheet lead thus presenting a continuous lead surface to the corrosive. Occasionally, large steel cut washers and round-head bolts are used to fasten sheet lead to the vessel shell which may be wood or steel. The bolt and washer in this case are covered with a lead cap which is welded to the lining. Bolts used in this manner are usually spaced over the lining on 18-inch centers.

In addition to bolting, fastening straps to support sheet lead linings more recently involve automatic stud welding which eliminates drilling of the steel shell and positioning of the lead sheet, with studs on 18-inch centers, 12-inch centers occasionally, but never more than 24-inch centers, and a comparatively new stud driver which eliminates drilling of straps and shell as well.

For both methods the advantages can be found in the following details of use.

- All fastenings made from inside of tanks.
- Elimination of outside scaffolding.
- Elimination of hole drilling.
- Elimination of countersinking of pre-drilled holes.
- Reduction in time-consuming marking by driving studs at random (not adhering to specific spacing).
- Eliminates the bolting operation.

- In the case of the stud driving method, elimination of external power sources.

- Success in lining of a full range of tanks (1/8 to 3/4 inch steel) and

- Actual job reports which indicate time savings of as high as 20 to 1 over the older method of drilling and bolting. Over-all cost savings have been about 60 percent and largely the result of lowered labor costs.

All in all when properly strapped or otherwise supported, sheet lead lined vessels can be used as reaction vessels where higher temperatures are encountered. In deep tanks, because of the high density of lead, loose linings must be strapped properly. When repairs are necessary they are easily accomplished and when the vessel's useful life has expired, the scrap value of lead constitutes a considerable reduction in the cost of new construction. Occasionally, in addition to strapping, a layer of acid-brick is placed over the lead lining on the bottom. The main purpose of this is to hold the lead in place and to prevent strain from open or ruptured coils from eroding lead. The prime difficulty with using this type of bottom is that it is often necessary to tear up a large amount of brick when a leak occurs in order to locate the leak. New techniques in the use of radiography have been developed, however. Pioneering in this work, Sklar and Bracken* of Esso Standard Oil Company and Delve of Esso Research and Engineering Company found that radiographic inspection of lead-brick lined vessels is definitely feasible. They obtained radiographs that were useful in locating the cause of failures in a lead and brick-lined vessel, consisting of 3/16-inch lead bonded to [illegible]-inch steel and covered with a 4½-inch carbon brick. A 500 millicurie cobalt-60 source was used at 36 inches, with a 12-hour exposure of an entire 24-inch manhole area. An extension of this technique to the aforementioned bottom construction is apparently feasible. As outlined later, radiographic techniques are especially useful as a means of avoiding the sometimes excessive loss in time due to unnecessary removal of the brick lining.

In the realm of inspection, sheet lead installations may be tested for imperfect welds or pinhole penetrations with fluorescent and dye penetrants. It has been found practical also, to pump suitably dyed kerosine between the lead lining and the vessel shell followed by inspection of the interior for kerosine traces. Still another technique involves pumping of freon-laden air between the shell and the lining with leaks on the inside of the vessel being detected by a halide torch.*

Cage Construction. A further extension and somewhat of an improvement in sheet lead construction is the so-called cage construction which has among its attributes:

- Easy leak detection.
- Permits repairs from the outside.
- Where the vessel design calls for extra support of the lead lining, internal strapping and corollary piercing of the lead for fastening is eliminated and
- Lower material and erection costs and easier field construction by elimination of unwieldy steel sheets.

It is customarily good practice to provide "weep holes" in the loose lead lined steel tanks but unfortunately the corrosives do not always follow a detectable path in the event of failure. Drippings cannot be depended upon to drain at the nearest weep hole and therefore they serve only to indicate the occurrence of a leak and not necessarily its location. The importance of leak detection and cage type construction therefore go hand in hand.

Fabrication. In place of the usual steel or wooden shell lined with sheet lead, a basket or cage-like structure comprised of steel flats and angles welded together to form an open frame is used for supporting the lead lining. Strips of lead are burned from the outside over horizontal steel straps, thus supporting the lead externally. Depending on the height of the vessel, the straps are closer together at the bottom than at the top to give the necessary support where hydrostatic pressure is greatest. Visual inspection for leak detection in most cases suffices. During fabrication defects may be detected by the applicable method previously outlined for sheet lead construction.

Brick and Lead Linings. An important method of construction for handling the most severe conditions is the use of a lead membrane between the steel vessel shell and an acid-brick inner lining. This type of construction has been proved effective in a large number of installations where lead by itself, or other materials of chemical construction, are inadequate. When properly designed and installed, they will perform admirably under the most severe conditions.

The following summarizes the conditions which warrant the selection of lead-brick construction and the experience acquired over the years which has contributed to its use, recognition of its value, and ultimately to extensive, widespread, and continued employment in the chemical processing industries:

- High temperatures: Bricking permits temperatures beyond the physical limitations of lead. Lead-brick construction is frequently used where the temperatures are in excess of 500 F. and even as high as 1000 C.
- High pressures and vacuum: Certain acid recovery units are brick and lead lined and operate under vacuums as low as 0.25 inch of mercury at about 260 F.
- Abrasion and erosion: Brickwork reduces the scouring effect of violent agitation found, for example, in sulfuric acid concentrators.
- Thermal insulation: Essentially eliminates heat loss and excessive temperature fluctuation as often encountered under rapidly fluctuating time-temperature cycles.
- Substantial cost savings: Ample proof of the economy of brick-lead combinations is the fact that corrosion resistant masonry construction composed of a suitable shell, lead membrane, proper brick work and cement can be depreciated over a long period of years, 15 years being not uncommon.
- Corrosion: Brick and lead perform very effectively over the range of sulphuric acid, alum, and acid-alum concentrations.

Here are some of the basic fundamentals which are observed in the

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FIGURE 1—Three vacuum concentrators more than ten years old have been operating continuously on 40—82 percent sulfuric acid used for distillate treating.

type of construction in addition to the design of the tank which is built to support the weight of the entire structure:

1. Bottom should be dished where pressure is involved and the welds placed at or above the bottom edge.

2. The lead lining is applied after removal of all burrs and other projections on the inside of the tank which may cause injury to the lead. Chemical grade 8 to 10-pound sheet lead is usually adequate and is found in use generally.

3. The lead should be lapped over the top of the vessel to prevent seepage between the lining and the steel and loose sheet lead sides should be lapped over the bottom sheet about 4 inches and welded together around the entire exposed edge. In very large vessels, however, or at high operating temperatures, it is advisable to strap the lead to the outer shell. Inasmuch as lead will usually conform to the same general shape as the steel backing, it is desirable to obtain as smooth a steel surface as possible without abrupt changes in shape. At times bonded lead construction is required for reasons already outlined and surfacewise does not present a problem.

4. After the lead has been installed and tested, it is lined with one or two courses of brick chosen according to several factors, degree of acid resistance required, minimum allowable porosity and degree of thermal gradient of shock.

5. Furthermore, steps are taken to avoid contact with sodium ions in acid-proof cements. This is done by bonding asbestos paper to the lead with potassium silicate solution before the brick work is installed. Also a sheet of asbestos is utilized with resin base cements similarly. With sulphur-based cements an asbestos membrane is not needed.

6. A sufficient thickness of brickwork is installed such that temperatures at the surface of the lead will be reduced to 125 F. in the case of bonded lead, and 165 F. in the case of sheet lead. The temperature restriction for bonded lead is only applicable where tinning has been used for preparation of the steel surfaces. Skiba's treatment accomplished bonding without tinning at all, and in the method reported the temperature restriction does not apply.

7. With regard to another item on the thickness of the brickwork, an attempt is made to keep a sufficient thickness such that mean temperatures are reduced so that with increasing temperature the brickwork will be elongated more than the steel shell. The resultant differential expansion holds the lead in compression thus assuring more than adequate support.

With regard to testing, assuming faultless lead construction and no damage to the lead lining during the bricking-in process, with actual service, the procedures as recommended by Skiba and Bracken,[6] are recommended for expeditious handling of leakages as they occur. When properly utilized all but the necessary tearing up of brickwork is preventable. A variation in acid-brick and lead membrane construction may be seen in the accompanying Figures 1, 2, and 3.

Other Developments. To add further to the latest in lead construction practices, it is well worth noting the successful application of the technique of coating steel with lead by spraying.[7] This is done by spraying a mixture of finely divided metallic lead mixed with a volatile wetting agent at extremely low pressures with a high volume of air. When applied, the wetting agent evaporates out in a matter of minutes, leaving the metal deposited on the surface. The spraying operation is repeated twice more leaving a deposit of lead approximately 14 pounds to 80 square feet of surface or to a thickness of 10 mils over-all. This technique is now being used extensively in various installations throughout the U. S. to prevent corrosion of tubing and pipe, on the OD and the ID of tanks, oil treaters, gasoline plants, refineries, spray and cooling towers and structural steel work which are subject to corrosion encountered in the field. For example, lead applied in this manner has been in service in gasoline plant cooling tower piping as a protection against highly corrosive cooling water for more than 10 years with no signs of failure. It has also been used for interior protection of piping for secondary recovery systems for more than 13 years with the same results.

In the areas where lead pipe, valves, fittings and pump connections and lead return bends of sluice pipes find service in refining processes, lead has chalked up an impressive record. Very little can be added therefore with respect to these uses. Bonding techniques similar to those described

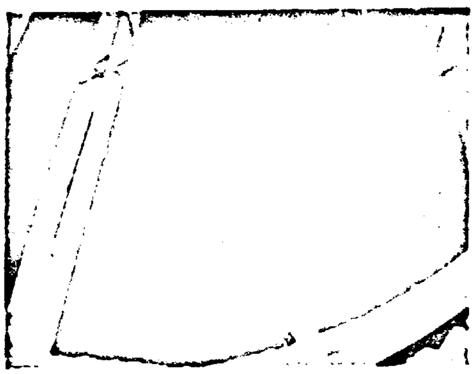

FIGURE 3—Lead lining further protected from corrosion by double acid-brick lining.

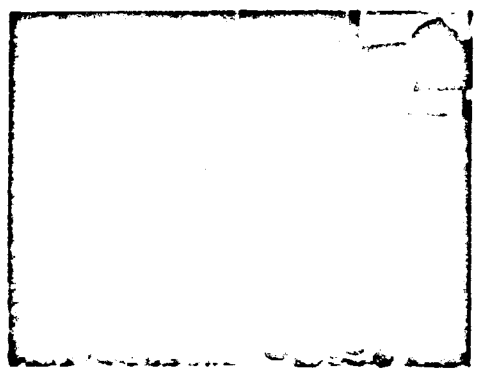

FIGURE 2—Vacuum concentrator body sections are lined with half-inch lead sheets.

can be used in the manufacture of lead lined steel pipe and lead covered copper heating coils with good results. Aside from the same general fluxing requirements, molten lead is cast on in sections by rotating the pipe. Another method involves inserting an extruded lead pipe into a suitably prepared steel pipe with the lead pipe being expanded against the outer shell by steam pressure. Temperatures which permit bonding are thus obtained. Lead covered copper pipe is fabricated similarly by variations of the casting method involving a mold.

Informative Case History. In this case history, there is excellent material on the sequence of events and steps taken in improving the serviceability of lead by proper design in an acid-alum reactor used in the production of aluminum sulphate (alum) as well as information on the various other uses for lead in this particular area.

Introductory History. Approximately 13 years ago, a total of 125 tons of lead was installed to handle the production of corrosive alum solutions in a bead catalyst plant where nearly two billion beads or 50 tons of finished catalyst per day are produced. The catalyst is used in the thermofor catalytic cracking process which at the time had recently come into extensive use in the production of high-octane gasoline. The beads are produced in lead lined forming towers from gel forming solutions consisting of sodium silicate and acid-alum (aluminum sulfate). Alum is produced in an acid-alum reaction tank from aluminum trihydrate reacted with sulfuric acid.

Process. Demineralized water is first introduced to the alum reactor whereupon sulfuric acid (66 degrees Bé) is added until the solution is 50 percent acid, filling the tank to a depth of 18 inches. The temperature resulting from the exothermic reaction is further increased by the addition of aluminum tri-hydrate (purified alumina) to 240 to 260 F. Additional alumina is added to maintain this temperature, and the reaction is continued for 1½ to 2 hours while continually agitated with steam which keeps the aluminum sulfate above its solidifying temperature of 210 F. After the reaction is completed, the batch is then diluted to make 23 percent aluminum sulfate which is kept for 4 hours at 130 to 140 F. Further dilution produces a 20 percent alum solution which fills the tank to 9/10 full and is liquid at room temperatures. The solution is then pumped out of the tank into a lead-lined solution preparation tank where it is further diluted to 10 percent. The average service of the reactor is one batch per day. It is readily seen that the combined effects of differential or cyclic heating, constant agitation, and abrasion and temperature level contribute to what is one of lead's severest tests.

Equipment and Performance. The reaction tank is 17 feet, 7 inches on the ID and 7 feet, 1 inches in depth, and was lined initially with 16-pound chemical lead supported by vertical straps 4 feet apart. This proved unsatisfactory after only five months operation and was consequently ripped out. Severe physical distortion of the lead had occurred and subsequent penetration of the alum solution resulted in replacement of the steel bottom and sides to a height of 18 inches.

Since corrective steps were obvious and were dictated by the physical limitations of lead and not its specific resistance to the corrosive, a new tank lining was installed and put into service. Its bottom and sides were lined with 22-pound tellurium-chemical lead, and the slightly convex top, with 12-pound chemical lead. The additional straps consisting of half-oval steel covered by 16-pound tellurium-chemical lead 7 inches wide were installed to give support every 24 inches on the side wall in contrast with the original 48-inch spacing. The bottom was secured by parallel straps sheathed with 16-pound tellurium-chemical lead 16 to 18 inches apart and 5 inches wide bolted through the steel tank to supporting steel I beams beneath.

Repairs of this lining were not necessary until 16 months later when sporadic patching became increasingly frequent. All repairs were made with chemical lead rods. The walls showed the least amount of bulging or sagging between the straps, and required the least repairs. Corrosion was least in the lower third of the vessel wall but above that, the wall area was exposed to hot corrosive

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foam in the presence of air, and some corrosion had taken place along the crests of the bulged lining. On the bottom, cracks and perforations had caused considerable trouble. Lead between the strapping had bulged in some cases as high as 3 inches above the tank bottom.

Trouble with the lining was severe because the product formed is liquid aluminum sulfate which seeps through occurring hair cracks into the cavity under a lead bulge, filling it, and later solidifying when the reaction ceases. Flattening of the bulges is prevented therefore and the bulge has to be cut open, and the solidified aluminum sulfate removed. Leaks were detected by weep holes; the presence of $Al_2(SO_4)_3$ being noted by the appearance of stalactites.

This difficulty at the bottom was due primarily to the appearance of fine cracks adjacent to the welded seams, on the seams, on or adjacent to welds from earlier repairs, or along crests of the bulges, a usually predominant occurrence.[7]

An attempt was made to correct the situation by using a brick lining to provide uniform support of the lining and also to insulate against the extremes of temperature and fluctuations thereof. However, the cementing compounds used did not withstand attack by the solution and eventually the bricks loosened and proceeded to swirl around causing damage to the lead lining (or membrane) and to the agitating equipment as well.

The reactor was later relined with a brick-lead membrane lining using a suitable cement. This trial installation after a few initial leakages remained in service practically trouble-free for five years. In fact, failures after five years of this type of service were expected. The only real difficulty presented at the time was not due to the repairs necessitated but rather to the difficulty encountered in finding the leaks. The weep holes were to no avail and the brick lining prevented the exact location of the leaks. Attempts made in repairing the lining resulted in a great wastage of man hours and extensive, unnecessary tearing up of different parts of the lining. In short, test methods at the time were insufficient to cope with the problem of locating a leak under a brick lining quickly.

In contrast to the situation 4 or 5 years ago, sufficient information has been reported in the literature as previously described which precludes the possibility of removing a serviceable lead-brick lining for want of sufficiently adequate test methods or techniques for determining the location of flaws or leaks.

Taking advantage of the techniques made possible by the advance of nuclear science, leak detection in lead-acid brick linings might be facilitated by the use of low level radioactive tracer-solvent methods which would depend upon the amplifying effect that a lead membrane would have on a gamma radiation-induced signal from a fluid source behind the lining. This could be accomplished by introducing a soluble radioactive element into water which would then be pumped between the lead membrane and vessel shell. Scintillation counters could be used to monitor the inside surfaces of the vessel in order to detect any intensification that would be indicative of a leak. After or before effecting repairs in this manner, detergent cleaning or chelation could be employed to remove vestiges of the tracer used.

Further use of such techniques may be had with respect to bonded lead linings or even sheet lead or cage construction and with or without brick. In this case, the vessel would be filled with the fluid source and the outer surfaces monitored to detect intensification of signals which would be indicative of imminent failure. However, calibration studies would be required and extensive measures may be necessary in the case of brick liners to remove traces of the radioactive constituent when it presents a problem.

Even considering possible limitations, the advantages of the aforementioned techniques are indeed provocative. Aside from the suitability of various test methods, installations similar to the one under consideration give up to 15 years' service. In short, lead lined alum digestors usually perform well from 9 to 11 years before the first leak occurs with the second often occurring between 10 and 15 years.

To sum up the situation at the bead catalyst plant, the bead forming towers lined with $^{3}/_{16}$-inch chemical lead supported by a single steel strap at the top are still unaffected by corrosion from the dilute acid and aluminum sulfate solution, 5 percent H_2SO_4, 5 percent $Al_2(SO_4)_3$, 90 percent demineralized water at room temperature, after 13 years service.

Lead lined storage tanks containing acid-alum solutions diluted to 20 percent strength, and solutions further diluted for introduction to the bead forming towers, are still giving good service to date after 13 years.

A large proportion of the piping in this installation is lead which has been extended beyond the design stress levels without eventful failure and is still in good shape attesting to the durability of lead in this application. Lead pipe, valves and fittings in pump connections and lead return bends of sluice pipes under forming towers are all showing excellent usage.

About the Author

Edward J. Mullarkey is technical director of Lead Industries Association, New York, where he gathers and correlates available technical information about all phases of lead usage. In addition, he disseminates the information so that it will be useful to government and industry, and will assist lead users in the solution of technical problems involving lead. He also investigates areas where research might be necessary or valuable, and generally supervises such research. Mullarkey is a graduate of New York University where he received a B.S. degree in metallurgical engineering. He was formerly with the Arma Division, American Bosch Arma Corporation.

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