

Present Industrial Significance of Lead

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The "Present Industrial Significance of Lead" is what I have been asked to tell you something about. No doubt many of you have had direct contact in your own work with lead in industry, but perhaps your experience with it has of necessity been limited to only certain phases of its industrial applications. I think I can correctly say that lead has broader industrial significance than any other nonferrous metal. By that I don't mean that it is the most used metal in point of tonnage but that its influence is felt in a greater variety of industries and in more different ways. For this reason I feel that some understanding of its industrial significance is essential to the medical man who would intelligently approach lead hygiene in industry.

Consumption of Lead

Last year more than 1,100,000 tons of lead were used in the United States. In fact consumption of lead in the United States has averaged just under 1,000,000 tons a year over the last ten years. Obviously this is a sizable tonnage of a metal that now sells for \$260 a ton and has sold considerably higher in the last two years. It indicates the magnitude of the industrial applications of lead.

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-2-

The interesting thing, however, is the variety of industries and variety of products into which this tonnage of lead enters. In the first place nearly a third of all the lead used last year went into chemical compounds like white lead, red lead, litharge, lead silicates, lead chromates, lead arsenate, and tetraethyl lead, to name only the more important few.

The other two-thirds of the lead consumed is largely in metallic form either as pure lead or as alloys. Among the more important products in this group are storage battery grids, cable sheathing, pipe, sheet, solder, babbitt, type metal, calking lead and many others.

I think here a breakdown of lead consumption in 1948 by products may be enlightening. This is given in the following table:

LEAD CONSUMPTION BY PRODUCTS

1948 In Short Tons	
Litharge	121,000
Tetraethyl Lead	84,000
White Lead	36,000
Red Lead	28,000
Lead Arsenate	17,000
Lead Chromates	16,000
Miscellaneous Lead Compounds	24,000
Total Lead Compounds	326,000
Antimonial Lead Products	230,000
Cable Sheathing	175,000
Solder	68,000
Bearing Metals	41,000
Calking Lead	40,000
Pipe & Extruded Products	36,000
Rolled Products	31,000
Type Metal	29,000
Miscellaneous	128,000
Total Metallic Products	778,000
Total	1,104,000

Another way to break down these consumption figures is by industries rather than by products. While it is difficult to make a clear-cut separation in this respect, yet it is probably a more interesting and valuable breakdown from your standpoint. Here is such an approximate analysis:

-3-

LEAD CONSUMPTION BY INDUSTRIES1948
In Short Tons

Storage Batteries	355,000
Cable	175,000
Construction	105,000
Oil Refining & Gasoline	96,000
Paint & Varnish	69,000
Ammunition	42,000
Printing	29,000
Railroads	24,000
Automobiles (other than batteries)	20,000
Insecticides	17,000
Colors	16,000
Can Manufacturing	14,000
Chemicals	7,000
Collapseable Tubes	7,000
Coatings	5,000
Rubber & Hose	4,000
Steel & Wire	3,000
Foil	3,000
Brass Manufacturing	2,000
Powder	1,000
Unclassified	108,000

Total 1,104,000

It is clear that the foregoing is not strictly on an industry basis because of the difficulty and even impossibility of tracing the ultimate disposition of a number of lead products. Yet in most cases it indicates quite clearly the industry in which the lead is fabricated and where, if there is a hazard, it may occur unless properly controlled.

It certainly must be clear from this tabulation that there are many industries which to a greater or less degree depend upon lead or its products. Yet I think that to be of benefit to you it is necessary to go beyond any such general summary as I have presented and to examine exactly in what form and in what manner these industries employ lead.

Storage Battery Industry

Let us then start with the largest user of lead, the electric storage battery industry. Before we discuss the way lead is used in that industry, you may wish a little background information about batteries themselves. There are two types of electric storage batteries which are of industrial significance - the lead-acid battery and the nickel-iron-alkaline or Edison battery. The former has many times the industrial significance of the latter because it is the lead-acid battery which is used for automotive starting and lighting. It is the only kind which will deliver the high current densities over short periods of time which are required for automotive engine cranking. Furthermore, while for other

applications the nickel-iron battery may have a longer life, it is much more expensive.

There is a third type of battery about which you may have read recently, as it has received rather sensational and I feel, unwarranted, publicity. This is the nickel-cadmium battery, manufacture of which recently started in this country although it has been made in a limited way in Europe for some time. It has many drawbacks such as high cost, great weight, large size, and poor operating characteristics at low temperatures, which, coupled with limited supplies of cadmium, has caused the best-informed people to see little possibility of its use in the automotive field.

Therefore, by far the bulk of the storage battery business falls on the lead-acid type of battery since it is used for all automotive batteries, which accounts for 75 per cent or more of the total battery business, and other batteries as well. Batteries for new cars amount to 5,000,000 or 6,000,000 a year at current rates of production. Even more important is the replacement automotive battery business because the average life of an automobile battery is about two years. Thus in 1948 nearly 24,000,000 replacement batteries were produced and even with the decided drop in business earlier this year, some 17,000,000 or 18,000,000 replacement batteries will be produced in 1949.

The balance of lead storage battery production goes into a variety of industries. They are used as stand-by batteries by power companies, and in hospitals and places of public assembly, where power failures might be fatal. They are used in the telephone system, for railway car lighting, for industrial trucks, for railway and aircraft signals, for airplanes, for mine locomotives and many other purposes. They are the means of propulsion of submarines when submerged and these submarine batteries weigh 100 tons each or more.

The lead in storage batteries is in two forms - metallic lead to make up the grids, lugs, etc., and lead oxide, which is the active material pasted on the plates. The grids are made of a lead-antimony alloy containing between 8 and 12 per cent antimony, depending upon the preference of the individual manufacturer. These are made from metallic ingots of antimonial lead by melting and casting.

The oxides on the other hand are made from pure metallic lead. The oxides used are litharge (PbO), red lead (Pb_3O_4), and black oxide (Pb_2O).

Battery manufacturers generally buy the antimonial lead ingots used to make the grids from either primary or secondary lead refineries. A few battery companies, however, also operate secondary smelters wherein they produce their own antimonial lead from scrap batteries. The melting and casting of the grids is generally done in the battery plant, although a number of very small battery manufacturers buy the grids already cast from larger battery companies.

A few of the large battery makers produce their own oxides, while most battery companies buy the oxides they use from the lead manufacturers.

-5-

In assembling batteries lead welding is employed in the battery plants to connect the plates and battery connectors. About 60 to 70 percent of the weight of a battery is lead and this lead is about equally divided between metallic antimonial lead and lead oxide. About 80 percent of all the lead used in storage batteries is recovered at secondary lead smelters and this forms the basis of the large secondary lead smelting industry which last year produced nearly a half million tons of secondary lead and lead alloys.

Thus the storage battery industry is almost entirely dependent upon lead and there seems little likelihood at this time of any substitute appearing to take the place of lead in that industry. Because of the automotive industry's dependence upon the storage battery industry it, likewise, at least indirectly, is heavily dependent upon lead. In fact, according to a recent article in AUTOMOTIVE INDUSTRIES, there are more pounds of lead used per car, if batteries are included, than any other non-ferrous metal or alloy. And a car wouldn't be much good to us today without a battery because the number of electrical gadgets in a car is multiplied each year and they don't give us a crank or even a place to insert a crank except behind the steering wheel.

Cable Industry

The power and communications industries are also heavily dependent upon lead. Here it is used to sheathe the transmission cable which transports the energy from the source at which it is generated to the point at which it is consumed. Obviously generators and telephones or telegraphs are useless unless the power or messages can be safely delivered to the proper place.

The purpose of sheathing on cable is to protect the wires and insulation with a covering absolutely impervious to moisture and one which will withstand the corrosive attacks of soil and atmosphere for many years. At the same time this sheath must be sufficiently flexible to permit coiling and uncoiling of the cable, installation through manholes, to provide for ground movement, and must be economically applied to the cable.

Lead answers all these requirements admirably and as yet no entirely satisfactory substitute has been found. To date only a combination of aluminum and polyethylene has shown any indication of substituting for lead and these only to a limited extent because of certain drawbacks such as difficulty of application and jointing.

Lead cable sheathing is generally an alloy of lead with about 1 per cent of antimony. It is applied to the cable in an extrusion press. The pigs of lead or lead alloy are melted in a kettle adjacent to the press, often in a reducing atmosphere to prevent oxidation, and the molten metal allowed to flow into the cylinder of the press, where it solidifies. The unsheathed cable is fed into the cylinder through an opening at one side near the bottom and passes out through a die in the opposite side. The cable forms the core of the die and this die has a diameter equal to the outside diameter of the cable sheath. As hydraulic pressure is applied to the lead in the cylinder, the cable is fed through the die and lead is squeezed out around it in the space between the cable and the die. Thus a continuous, seamless sheath of lead is formed around the cable.

46

As I have already pointed out, some 175,000 tons of lead, or about 15 per cent of total consumption, were used in this way in 1948. This industry is to a very large extent, if not entirely, dependent on lead for protection of its transmission lines. This incidentally includes television which is transmitted from city to city over the telephone company's lead-sheathed coaxial cable. Think of what a lead sheath means to Arthur Godfrey and Milton Berle!

The power and communications industries to a much lesser extent depend upon a lead-tin alloy, solder, to make the joints in their lead-sheathed cable. Yet it is the ease with which such joints can be made and the dependability of those joints that give lead sheathing one of its distinct advantages over other types.

CONSTRUCTION INDUSTRY

The next industry in order of importance as a user of lead is the construction industry. Because of the difficulty of making an accurate separation, the term "construction industry" is here used to include not only ordinary building construction such as homes, apartments, office buildings and the like, but also some of the utilities which serve these buildings, like water distribution systems, and chemical equipment employed in industrial buildings. Lumped together, the construction industries used more than 100,000 tons of lead in 1948, or nearly 10 per cent of the total.

There are three principal lead products used in construction. They are pipe, sheet and calking lead. In ordinary construction, pipe is used in the plumbing system to handle plumbing wastes and in the water distribution system to conduct water from the street main into the house. It is rarely used for water distribution within the house. In industrial construction, it is also extensively used to conduct corrosive chemicals such as sulphuric acid and to handle corrosive industrial wastes.

Lead pipe is made in much the same way as cable sheathing. The lead is melted and flowed into the cylinder of an extrusion press, where it solidifies. At the top of the press is a circular die through the center of which extends a core or mandrel which also extends down through the lead and is fixed to the bottom of the cylinder. The core has an outside diameter equal to the inside diameter of the pipe to be made, and the die has an inside diameter equal to the outside diameter of the pipe. When pressure is applied, lead is forced out through the space between core and die as a continuous seamless pipe.

It may be interesting to note here that the manufacture of lead pipe is an extremely old industry dating back more than 2,000 years! As you know our modern plumber takes his name from the Latin word for lead, "plumbum". In the days of the Roman Empire lead pipe manufacture was well established, pipe being made in ten-foot lengths and 15 standard sizes. That pipe, however, was much cruder and was not seamless. The lead was first cast in a sheet, then bent up into the shape of a pipe and the longitudinal joint crudely welded. The age of these old pipes, many samples of which still exist, is easily determined because the name of the emperor ruling at the time of manufacture is cast on each length.

-7-

Sheet lead is used only to a limited extent in building construction, usually being confined to roofing, flashing, gutters and the like on the more monumental types of buildings or industrial or other buildings where special corrosion problems are involved. This is because of its relatively high cost and great durability. It is also widely used as a waterproofing for shower stalls and for X-ray room shielding. In industrial construction, however, large tonnages of sheet lead are employed to construct storage tanks, reaction vessels and other equipment for the manufacture and storage of corrosive chemicals.

Sheet lead is made by casting large slabs of lead several inches thick and weighing several tons. When solidified, these slabs are placed on the rolling mill and cold rolled to the desired thickness.

In ordinary building construction work both lead pipe and sheet are usually joined by soldering with conventional lead-tin solder. In chemical construction, however, lead welding (commonly called lead "burning") is more frequently employed because corrosive chemicals generally attack solder. By welding, no metal but lead is exposed to the corrosive. Lead welding is a true homogeneous welding operation, but it is conducted at much lower temperatures than welding of most other metals, notably steel. In fact, care must be taken not to overheat the lead and burn a hole right through it, since lead melts at only 621 deg. F.

Calking lead, the other important lead product used in construction, is simply soft metallic lead either in large pigs or small ingots or cokes. Its main use is to make joints in cast iron water or soil pipe of the bell and spigot variety. The pigs or ingots of calking lead are simply melted, usually at the site of construction, and are poured by ladle into the pipe joints into which strands of oakum have already been calked to partly fill the joints. After the lead has solidified in the joint, it is calked to make a tight joint and take up contraction of the lead on solidification and cooling.

PETROLEUM INDUSTRY

The next industry we may consider is the petroleum industry which only last year for the first time in peacetime stepped into fourth place as a lead consumer. Actually this industry uses much more lead than statistics show, because it employs large quantities of sheet lead and lead pipe in the construction of corrosion-resistant equipment. Since it is impossible to segregate that tonnage from other sheet and pipe used for similar purposes in other industries, the lead used by the petroleum industry for construction purposes is classed in the category of construction just discussed.

Therefore, we are now considering only the chemical compounds of lead which enter into the refining process or become a part of the gasoline itself. These alone totaled 96,000 tons of lead last year, almost equalling the construction industry.

-8-

In oil refining, litharge is used in the so-called "doctor solutions" which break up undesirable sulphur compounds present. The litharge is dissolved in caustic soda and, when added to the petroleum products, reacts with the sulphur compounds and is removed as lead sulphide, thus taking the undesired sulphur with it. About 12,000 tons of lead as litharge is thus consumed.

Most sensational of lead's newer developments has been tetraethyl lead used as an anti-knock ingredient in motor fuels. Only about 25 years ago this use of lead was unknown. Last year it consumed 84,000 tons of lead, with productive capacity being further increased this year.

I think this typifies one important thing about lead, namely that its industrial significance is not dependent upon only a few attributes, but rather on a wide variety of both chemical and physical properties. We all know that changes in our industrial economy frequently outmode certain uses of any material. Because lead is so versatile, as old uses become outmoded new ones seem almost inevitably to crop up.

As an example, in a few moments I will discuss the changing pattern of the use of lead in the paint industry, wherein the volume of lead used has declined over the last 25 years. During that same period, however, the use of lead in tetraethyl lead has shown about a corresponding increase. These two applications are both dependent upon chemical properties of lead, but each upon different chemical properties.

Tetraethyl lead is one of the few liquid compounds of lead of commercial significance. It is a colorless liquid with the formula $Pb(C_2H_5)_4$. It is manufactured from a lead-sodium alloy by treating the alloy with ethyl chloride. After completion of the reaction, the product is distilled with steam to recover the tetraethyl lead.

The anti-knock fluid is a mixture of tetraethyl lead with ethylene dibromide, Halowax, and a red aniline dye, the latter to identify it from non-leaded gasolines. While there are refining methods which can be used to increase the anti-knock rating of gasoline, that rating can always be further improved by the addition of tetraethyl lead. With the automotive industry tending more and more to higher compression engines requiring fuels of increasingly high anti-knock rating continued expansion in the use of tetraethyl lead is to be expected. Yet about 3 cc. of tetraethyl lead per gallon of gasoline seems to be the maximum amount that can be added efficiently. Beyond that amount its effectiveness seems to fall off rapidly.

The anti-knock fluid containing tetraethyl lead is made in the plants of its two producers in this country and shipped to the oil companies for blending with their gasolines.

PAINT INDUSTRY

The paint industry, with nearly 70,000 tons of lead consumed last year, is still a very important user of lead products, but is nowhere near the consumer it was 25 years ago. In this industry it is used in a variety of forms. It is an important pigment in house paints. For that purpose it is employed as basic carbonate white lead, basic lead sulphate, leaded zinc oxide and certain lead silicates. Basic carbonate white lead was once the backbone of outside house paints, but over the last 25 years its use has gradually contracted due to the fact that it costs the paint manufacturer more to put it into his paint than any other white pigment. In that highly competitive industry some of the qualities that white lead imparted to paint have been sacrificed. However, most paint manufacturers still agree that a certain amount of lead pigments is needed in outside paints and most of them formulate their paints on that basis.

The basic carbonate was formerly made almost exclusively by the famous "old Dutch process" which required three or four months to convert the lead to the basic carbonate in stacks through action of acetic acid, moisture and spent tanbark. In recent years the trend has been toward quicker processes involving electrolysis, chemical precipitation and other methods to reduce cost so that just this year the last "old Dutch process" stacks in this country went out of existence and that process is no longer used.

There are several quick processes. In one metallic lead is melted and blown with air or steam to a fine powder. It is placed in large rotating wooden drums, into which acetic acid and water are periodically sprinkled. Heated air and carbon dioxide pass continuously through the drum. The reactions are the same as in the old Dutch process but, due to the finely divided form of the lead, the conversion requires less than two weeks.

In one of the chemical processes lead is dissolved in acetic acid to form basic lead acetate and the basic carbonate is precipitated by passing carbon dioxide through the solution.

In the electrolytic process the lead acetate solution is obtained by electrolytic decomposition of metallic lead anodes, the basic carbonate being precipitated almost immediately by sodium carbonate in the solution.

Basic sulphate white lead, also used extensively in paints, is made either by a fuming or chemical precipitation process. Leaded zinc oxide is generally a product of fuming and the newer silicates are produced chemically. All enter into the manufacture of outdoor paints. None of the white lead pigments is today employed in the manufacture of indoor paints.

Red lead (Pb_3O_4) is still the world's standard pigment for metal protective paints. It is successfully meeting the competition of newer pigments, and is used either by itself with linseed oil or other suitable vehicles, or mixed with other pigments, usually in smaller amounts, and the proper vehicles. Red lead is made by further oxidation of litharge at carefully controlled temperatures.

-10-

Another lead pigment, blue basic lead sulphate, is also used in metal protective paints. It is made directly from lead concentrates by fuming and is a mixture of basic lead sulphate, lead sulphite, lead sulphide, zinc oxide and a very small amount of carbon.

Lead compounds are also used as driers in paints but they are included in exceedingly small quantities per gallon of paint.

Colors

Closely allied to lead's use in the paint industry is lead's employment to make certain colored pigments, notably the lead chromates. This industry consumed about 16,000 tons of lead last year. Most of the yellows, greens and reds are lead chromates, either alone or precipitated with other pigments. These are made by chemical precipitation starting generally with litharge as the raw material. They are also used as colors in printing inks.

I will not attempt to go into as much detail about the smaller uses of lead as I have in the cases of the five principal consuming industries - storage battery, cable, construction, petroleum and paint. Nevertheless, I think it is important to review some of them briefly.

Ammunition Industry

The ammunition industry is an old stand-by in the lead picture, using around 40,000 tons in a peacetime year and several times that amount in a peak war year. Bullets for small arms are lead alloyed with up to about 2-1/2 per cent antimony. They are molded from sections cut from extruded rod. Shot for shotgun shells, which is more important than bullets in peacetime, is usually made of lead alloyed with small amounts of antimony and arsenic. It is melted and poured through a sieve at the top of a shot tower. It forms into spheres as it descends and is caught in water at the bottom. Large shot is cast.

Printing Industry

The printing industry uses about 30,000 tons of lead a year in the form of various alloys with antimony, tin and sometimes a little copper. The exact composition depends upon the application, that is, whether it is for linotype, monotype, stereotype, or electrotypes metal. Melting, casting, and remelting and drossing are the principal operations involved. Type metal is used over and over and also circulates back and forth between the printer and the manufacturer, the latter cleaning it up and adding new metal to bring it back to proper composition after frequent use.

Railroad Industry

The railroads of the country consume some 25,000 tons of lead a year, mainly in bearings. In some cases, the railroads make their own bearing metals but more often they buy them from bearing metal manufacturers. Incidentally in a great many types of bearings the

-11-

lead content is much higher than before the war. This came about from the necessity of substituting lead for scarce tin during the war with the result that the higher lead content bearings were found to do the job well and at less cost.

Automobile Industry

The automobile industry employs about 20,000 tons a year in uses other than storage batteries. These are mostly as solder and some bearing metal. The solder is largely used for the radiator, which is soldered by a dipping operation. Body solder is also used to smooth out joints and other irregularities in the body surface. It is sometimes called filler metal, which aptly describes it. Automobile body repair shops are large users of body solder to help repair the wounds incurred in modern traffic.

Miscellaneous Uses

The farmer is a big user of lead as an insecticide. About 17,000 tons were used last year and this figure has at times been much higher. Lead arsenate is the compound employed, made by chemical reaction on litharge.

The tin can industry uses 14,000 tons of lead in a year just for soldering seams and closures. In addition it uses an inseparable amount, classed under coatings, in the form ofterne plate to make certain types of cans for non-food items. Terne plate is sheet steel coated with an alloy of lead and tin, the lead content of the coating usually running between 80 and 90 percent.

The ceramic industry is not as large a user of lead as it once was, but since the addition of lead compounds makes superior glasses and glazes for certain purposes, it still consumes about 10,000 tons a year. Most of this is in the form of lead oxide or lead silicate. The finest glass tableware and optical glass contain lead compounds and it is interesting, as a recent development, to note that glass television tubes may contain as much as 30 per cent lead. Lead silicate is an ingredient of many of the glazes for bathtubs and the like.

Here I would like to mention another relatively new use of lead in the plastics industry. Lead silicates are employed as light stabilizers in many plastics. The lead content, however, is usually small, amounting to only a few per cent.

The only other use of lead that amounted to more than 5,000 tons last year is in collapsible tubes. The tubes are manufactured by impact extrusion from discs cut out of lead alloy sheets. The alloy usually contains around 2 per cent antimony. When the tubes are to contain a substance that might conceivably be contaminated by contact with lead, the lead sheets from which they are made are rolled with tin on one or both sides. Also special wax liners are often used in lead or tin-coated lead tubes.

-12-

I cannot leave this discussion of individual industries without a word about the lead pencil industry. When the Tariff Act of 1930 was first written included by Congress in the schedule of duties on lead products was the item "lead pencils". Fortunately that was corrected before the Act was passed. Still more apropos of our subject was an item some years ago in the Toledo Blade, a leading newspaper, which reported that a man had died of lead poisoning as a result of sticking himself in the arm with the point of his lead pencil. I just mention these as an example of the kind of misinformation that often circulates and so that I can go on record as saying that lead pencils are not lead.

Conclusion

From the foregoing, which I hope has not been too tedious, I think it is obvious that lead's industrial significance is immense today and that the question of lead exposure in industry is not a simple one. For instance, merely to know that a man works in a lead plant or even works with lead is no indication of his exposure. There are all sorts of varying degrees of exposure, both as a result of the processes used and the form in which the lead is handled. It is likewise obvious, I think, that a great number of people working in the lead industries may have no dangerous exposure to lead.

I don't mean in any way to minimize the importance of hygiene in the lead industries. Certainly the Lead Industries Association has been fully cognizant of the problem for many years. It has made numerous monetary grants for research on this problem. We have established a health and safety division under your good friend, Manfred Bouditch, to cope with it both within and without the industry.

But I am equally convinced that all too often an incomplete understanding of the lead industries themselves has contributed to mistakes, abuses or what you will that have resulted in no good to any one. Therefore, I appeal for thorough study of each individual case, that our attack on the problem may be ever more enlightened.