INDUSTRIAL IMPORTANCE AND USES OF LEAD*

By Robert Lindley Ziegfeld
Secretary, Lead Industries Association

The "Industrial Importance and Uses 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.

LEAD SMELTING AND REFINING

Before proceeding to a discussion of the industries that use lead and lead products, I think some word about the lead smelting and refining industry in this country is in order. This industry is divided into two parts - primary and secondary smelting and refining. The former produces pig lead essentially from ores and concentrates with a small admixture of scrap and the latter from scrap, mainly old batteries, cable sheath, solder, babbitt and the like.

The ores and concentrates are produced mainly at mines in this country but a sizable portion is imported. Last year about 340,000 tons of primary lead was produced from domestic ores and 160,000 tons from imported material.

Secondary smelters are also of great importance and in 1954 produced pig lead, antimonial lead and other lead alloys totaling about 480,000 tons. The rest of the lead used in the United States is imported as pig lead and produced at foreign smelters and refineries.

It is obvious that smelting and refining is a big industry. Primary smelters are relatively few in number and generally large. Secondary smelters are large in number and range in size from very small, producing only a few hundred tons a year, to quite substantial operations.

Smelting generally involves the use of blast or reverberatory furnaces, although some small secondaries merely smelt and dross. Refining is by fire in this country except at one plant, which uses the electrolytic process.

*Presented at Postgraduate Course of Physicians on "Modern Consideration and Methods in Handling the Lead Problem in Industry," Institute of Industrial Health, University of Cincinnati, Cincinnati, Ohio, November 7-11, 1955.

CONSUMPTION OF LEAD

Last year more than 1,075,000 tons of lead were used in the United States. In fact, consumption of lead in the United States has averaged just under 1,100,000 tons a year over the last ten years. Obviously this is a sizable tonnage of a metal that now sells for $310 a ton and has sold considerably higher on two occasions since World War II. It indicates the magnitude of the industrial applications of lead.

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 40 per cent of all the lead used last year went into chemical compounds like white lead, red lead, litharge, black oxides, lead silicates, lead chromates, and tetraethyl lead, to name only the more important few.

The other 60 per cent 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, ammunition, pipe, sheet, solder, babbitt, type metal, calking lead and many others.

I think here a breakdown of lead consumption in 1954 by products may be enlightening. This is given in the following table.

LEAD CONSUMPTION BY PRODUCTS
1954
(In Short Tons)

Tetraethyl lead	161,000	
Litharge	117,000	
Black oxide (est.)	70,000	
Red lead	24,000	
White lead	19,000	
Lead chromates	19,000	
Lead arsenate	6,000	
Miscellaneous lead compounds	12,000	
Total lead compounds		428,000
Antimonial lead products	183,000	
Cable sheathing	127,000	
Solder	65,000	
Calking lead	43,000	
Ammunition	37,000	
Pipe and extruded products	28,000	
Rolled products	28,000	
Type metal	26,000	
Bearing metals	20,000	
Miscellaneous	93,000	
Total metallic products		650,000
TOTAL		1,078,000

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:

LEAD CONSUMPTION BY INDUSTRIES
1954
(In Short Tons)

Storage batteries	325,000
Oil refining and gasoline	166,000
Cable	127,000
Construction	98,000
Paint and varnish	38,000
Ammunition	37,000
Brass manufacturing	27,000
Printing	26,000
Ceramics	20,000
Colors	19,000
Can manufacturing	16,000
Automobiles (other than batteries)	11,000
Railroads	10,000
Insecticides	6,000
Steel and wire	6,000
Foil	4,000
Collapsible tubes	3,000
Rubber and hose	3,000
Coatings	2,000
Unclassified	134,000
Total	1,078,000

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 principal 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 one of these two 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 heard as it has received rather sensational and, I feel, unwarranted, publicity off and on in the last few years. This is the nickel-cadmium battery, manufacture of which recently started in this country although it has been made in a somewhat limited way in Europe for some time. It has a number of drawbacks, the most important of which are high cost and limited supplies of cadmium and nickel, so that the best informed people see little possibility of its extensive 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 practically all automotive batteries, which accounts for 75 per cent or more of the total battery business, and many other batteries as well. Batteries for new cars amount to 6,000,000 or 7,000,000 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 1954 more than 23,000,000 replacement batteries were produced and 1955 production of replacement batteries will probably exceed that total.

The balance of lead storage battery production goes into a variety of industrie 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 submarines batteries weigh 100 tons each or more although atomic power has changed this picture and will be discussed later.

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. Latest developments tend to reduce the antimony content and add small amounts of arsenic and silver

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.

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 important substitution taking place 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, there are probably 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.

PETROLEUM INDUSTRY

The next industry we may consider is the petroleum industry which just in the last few years, has leaped into second 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 discussed later.

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 166,000 tons of lead last year.

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 5,000 tons of lead as litharge is thus consumed.

Most sensational of lead's newer developments has been tetraethyl lead used an an anti-knock ingredient in motor fuels. Only a little over 30 years ago this use of lead was unknown. Last year it consumed 161,000 tons of lead.

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.

An 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 30 years. During that same period, however, the use of lead in tetraethyl lead has shown a corresponding increase. These two applications are both dependent upon chemical properties of lead, but each upon <u>different</u> 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 .

As I have already pointed out, some 127,000 tons of lead, almost 12 per cent of total consumption, were used in this way in 1954. This industry is to a very large extent dependent upon lead for protection of its transmission lines.

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 almost 100,000 tons of lead in 1954 or nearly 9 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.

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

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°F.

Calking lead, the other important lead product used in construction, is simply soft metallic lead either in large pigs or small ingots or cakes. 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 construction of the lead on solidification and cooling.

PAINT INDUSTRY

The paint industry, with 38,000 tons of lead consumed last year, is still an important user of lead products, but is nowhere near the consumer it was 30 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 30 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 pigment 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 the last "Old Dutch Process" stacks in this country went out of existence in 1949 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.

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 19,000 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.

CERAMIC INDUSTRY

This industry now uses in the neighborhood of 20,000 tons of lead a year and recent developments indicate possible substantially increased usage. Most of it is in the form of oxides or silicates. Finest glass tableware and optical glass, as well as much glass for electrical purposes, contains large amounts of lead. Glazes for china and many structural clay products also contain lead. The porcelain enamel industry once was a much more important user of lead than it is today, but it is here that new developments indicate expanded usage. This is due to the perfection of porcelain enameled aluminum, whereas in the past most enamelling has been on steel and cast iron. Because of the lower melting point of aluminum, low melting enamels are required and this characteristic is best obtained through the use of as much as 40 per cent lead in the enamels. Most observers believe that porcelain enameled aluminum has a big future which has only begun in the last year or so.

AMMUNITION INDUSTRY

The ammunition industry is an old stand-by in the lead picture, using around 37,000 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 in split ring molds.

PRINTING INDUSTRY

The printing industry used about 26,000 tons of lead last 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 electrotype 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 consumed some 11,000 tons of lead last 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 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 11,000 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 heal the wounds incurred in modern traffic.

MISCELLANEOUS USES

The farmer is a user of lead as an insecticide. About 6,000 tons were used last year and this figure has been much higher. Lead arsenate is the compound employed, made by chemical reaction on litharge.

The tin can industry uses 16,000 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 of terne 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 per cent.

A relatively new use of lead is as a stabilizer in plastics. For this purpose a variety of lead compounds are employed, some inorganic and some organic. While the lead content is usually small, amounting to only a few per cent, the total use of this purpose amounts to several thousand tons a year. The principal use is in vinyl plastics for electrical cable insulation, but it is also used in this type of plastic for many other purposes such as floor coverings, hose, pipe and sheet.

Lead collapsible 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.

The iron and steel industry uses lead in several ways. Terne plate coatings have been mentioned, but heat treating baths are often molten lead. Lead in the form of shot is added to molten steel to produce free machining steel and, while small, this is a use that is growing.

Lead is also used in brass and bronze, either for the properties it imparts to bronze for bearings, for example, or for free machinability in brass.

NUCLEAR SHIELDING

There is one relatively new use of lead on which I have not touched. At the moment we know little about its exact magnitude or its future. This is the use of lead as a shield for gamma rays from radio-active sources, which has grown up around the atomic energy industry. No figures are available on the consumption of lead for this purpose but it is variously estimated at present at between 10,000 and 20,000 tons a year. Future development could make this one of lead's major uses.

Lead is the most efficient commonly available, low-cost material for this purpose. However, concrete, iron and other materials may be used. In general it may be said that lead is usually the choice where space requirements and portability are controlling factors. For example, laboratory shielding, shipping containers for radio-isotopes, submarine shielding and the like are usually lead. Viewing windows are very high-lead-content-glass. Special cements containing lead in various forms are used for special conditions, as around the ball joints through which remote controls are operated.

I can not 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 Bowditch, 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.