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LET'S LOOK AT LEAD IN 1963*

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When the Lead Industries Association adopted the slogan "Look Ahead With LEAD," it had good reason. Lead is not just another material with a long history- though it has that — but probably one of the most versatile engineering materials and raw materials that can be found.

No doubt you've become acquainted with some of the leading roles it plays in engineering and day-to-day life. It is the material of the toothpaste tube you pick up in the morning. It may be the connection pipe that brings water into your house so you can use the toothpaste. It provides the battery power to start your car so that leaded gasoline can flow from the lead-coated gas tank and get to the lead ceramic glazed sparkplugs to exert the force at your lead (litharge) cured tires to make the car go. It's probably in the paint on your house. It makes the solder connections of your radio. It sheathes the cable that carries your telephone call.

We'll try to look at the reasons for such a diversity of uses in this talk so that you can get some idea of how and where lead may help you solve a problem some day. Before we do, though, let's look at some of the newer uses of lead that are current technical news —

Thermoelectric power — Among the bewildering array of effects and devices arising through "solid state" physics is the practical generation of electric power directly from heat by simple thermoelectric generators. They are simple in that they have no moving parts. They produce an endless flow of current so long as the hot junction is kept hot and the cold ends of the n and p elements are kept cold. This makes a thermoelectric generator sound like a thermocouple or a transistor. It is actually both! If the device is simple, the theory behind it is not. It involves relative mobility of electrons in the crystal lattice and the mobility of the "holes." As a practical matter, the best materials for such a role are about half way between being excellent conductors of heat and electricity and very poor conductors (insulating materials). One material that fills all these specifications and appears to be a likely large-scale power source of the future is the intermetallic compound lead telluride.

It is worth noting that if current is forced to flow through such an element, a corresponding flow of heat is set up. Thus one end becomes hot and the other cold. The effect is now being used in small refrigeration devices.

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As practicing engineers you will usually have a convenient source of electric power without resorting to solid state physics and thermoelectricity. There are situations even today, however, where that advantages of thermoelectric power are sufficient to carry the still-high price tag. Military installations like submarines are likely candidates for it and may in fact be using it now. The SNAP III (secondary nuclear auxiliary power) source makes use of a nuclear heat source and lead telluride. One such unit is now in orbit in the Transit satellites. Transit IV has been operating continously since July 1961 and, barring contingencies like meteor damage, promises another five years of power at design specifications. Reduced power will be available from it for decades to come. Power reduction, of course, hinges on the isotope heat source choice. Other SNAP power sources rated in kilowatts and tens of kilowatts also probably use it, though the details cannot be known yet because of security classification.

To bring the focus a little closer to home, we might look at an installation of the thermoelectric power sources along the pipeline of the Northern Illinois Gas Pipeline Company. Its engineers had the problem of protecting the pipe against corrosion. One effective method, as you know, is the use of cathodic impressed current. Cost studies, however, indicated that the running of power lines along the route would be too expensive. What the engineers did have available was a cheap source of heat by burning gas from their own pipeline. Their solution, of course, was obvious. An interesting point is that the thermoelectric generators (100 w each) cost about the same as current rectifiers would have — thus the initial cost saving of the power line installation was pure credit. Northern Illinois Gas was the first to use this scheme. There are now many more such units throughout the gasfield areas of the United States.

On the debit side of the ledger is the present poor efficiency of the thermoelectric generator — about 5 per cent. Theoretical studies indicate that 20 per cent may be realized one day. This would put the generator in at least a competitive class with conventional power generation schemes and far ahead of actual performance for some small units.

Even 5 per cent efficiency is ample to justify the power source for many applications involving waste heat. Low recovery is of not much account when the Btu's are going up the stack anyway. On this basis, home power units are now ready for the market. They provide enough power from waste heat in the home furnace flue to drive water pumps in the hot water heating system or fans for hot air.

Piezoelectric ceramics — If you don't happen to be familiar with the jawbreaker "piezoelectric," it is as simple as the principle of many phonograph pickups. Piezoelectric materials are crystals or ceramics which produce a voltage when they are mechanically stressed. Conversely, they change shape or exert a force to do so when a voltage is applied across them. Thus, if you have a phonograph with a crystal or ceramic pickup cartridge the oscillation of the needle is converted to voltage by a piezoelectric material. A common one in many recent stereo sets is lead zirconate titanate, or PZT.

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The phonograph use is an obvious one. So is its use in Sonar — the same ceramic array being used as a sound transmitter and as a microphone. It is a bit puzzling, at first, to learn that PZT is turning up in gasoline engine ignition systems, flash guns, speedometers, automatic weighing equipment, electrostatic air filters, and a variety of other seemingly unrelated uses.

Those of you who have gotten greasy under the hood of a car know the layout of a typical ignition system. Power from the battery or generator is converted to high voltage by a coil (high voltage step-up transformer) and circuit breaker. The points of the breaker are subject to severe arcing and a condenser is added to the circuit to suppress this. Nonetheless, the "tune up" you just had probably involved a new set of points as well as a new set of plugs. Now, the ignition system of one manufacturer's small engines has been replaced by a new set of components including a PZT "spark pump." There are no points, condensers, "coils," or magnetos. A cam in the existing shafting of the engine literally puts the pressure on two PZT elements about half an inch long and a quarter of an inch in diameter. The result is a hot 20,000 volt spark. Theory to the contrary, the spark on start-up with a conventional system is not so "hot" as it is in normal running. It is in the warm up period when most sparkplug fouling occurs. Tests to date indicate that the use of the "spark pump" ignition system extends sparkplug life (even between cleaning and gapping) by a factor of five. There are, of course, no points in the system. Further, timing of the engine stays fixed. In place of a tune up, such an engine would get only a carburetor adjustment.

So much for PZT in power lawn mowers, outboards, marine engines, and, perhaps one day soon, automobiles.

By adjusting the voltage output and sensitivity of the piezoelectric system to fit the needs, it has been possible to pump up enough air pressure with a small rubber bulb to fire a flashgun when triggered. We understand that a light weight lifetime strobe light is under development for camera fans. The power will come from the muscles in their hands.

High voltage for an electrostatic precipitator in home air conditioning units is being generated with no more equipment than a cam on the fan shaft and a block of PZT.

Perhaps the zaniest development involves "fashion technology" if we prosaic engineers dare enter the realm of Dior. One novelty now being offered the fashion field is a PZT element built into the heel of a lady's shoe and connected to flash a small neon bulb at her toe with each step. Let's hope that the manufacturer doesn't skimp on his insulation or neon toe lights will go out — permanently — on the first rainy day.

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The other side of the piezoelectric coin — motion or force directly from voltage change — employs most of the PZT used today. In addition to its use thus as a "loudspeaker" in Sonar, it is the electro-mechanical transducer in ultrasonic washers and sound power units. The washers, now employed in deburring fine metal stampings such as electric razor heads, and in degreasing, scouring, and pickling industrially, are basically just a tank with PZT (or other) electric-to-sound power conversion units coupled to their undersides. The "other" units are usually lead stabilized barium titanate ceramic or nickel magnetostriction devices. PZT has the advantage of higher conversion efficiency and higher power loading per unit of surface than either of the others. It also tolerates higher operating temperatures than the barium titanate units.

The cleaning-scouring-emulsifying action takes place at the face of any hard solid object suspended in the bath. In a small unit of about 3 gallon bath capacity, about 100 to 200 watts of sound power at high frequency supplies the energy for cleaning. Because the sound waves impinge on the surface at between (typically) 25,000 and 40,000 times per second, the acceleration of the bath liquid is very high. It pulls away from the surface leaving a bubble of partial vacuum and crashes back on the return wave front with intense force. It will remove lipstick from a drinking glass in about 2 to 10 seconds (and does so at many hotels and restaurants every day).

Two other characteristics of ultrasonic cleaning are worth noting. First, the cavitation action described above is "focussed" into crannies and crevices. Thus, ultrasonic cleaning is most efficient at precisely the point where most other cleaning methods fail. Second, the sound energy is so intense under normal operating conditions that it shatters most of the microscopic life commonly found on dishes, biological laboratory equipment, or surgical instruments. It is now standard for cleaning surgical instruments in many hospitals. It may one day be a standard in every well-equipped home kitchen, too.

Today, it is safe to say that PZT is the best material known for such service. While this doesn't mean that better materials will not be developed, it does give this ceramic an edge in the field of ultrasonics. And even though the optimistic visions and claims of the 1930's have not been nearly fulfilled, ultrasonic power still seems to have a magic and interesting future ahead.

Electrically powered vehicles — The only thing new about battery powered vehicles is the set of economic facts of the post war boom. Battery powered cars and trucks were serious contenders to the Locomobile and other early gas buggies. They went out of fashion because of their limited range and the problem of obtaining fairly sizeable amounts of electric power to charge them.

Today, with every new home equipped with 60 or 100-amp wiring, high current drains are the accepted norm. Further, electric power is comparatively cheap — especially when the comparison is made with a high-compression, high-performance, high-powered automobile or truck engine that spends most of its time threading through city traffic or stopping for door-to-door deliveries on a city milk route. As a matter of fact, 4 to 5 miles per gallon is the average for milk delivery trucks. And such driving also leads to high maintenance for these motors. The cost of this maintenance has risen, in the post war boom, faster than any other cost of operating a car or truck. Finally, the very trucks that are piling up these high costs are operating over routes of 30 to 50 miles a day.

Even in the modest quantities they are being produced in today, electric trucks are found to be far less expensive to operate by dairies, bakeries, dry-cleaning and laundry firms, and others who must send trucks through city traffic over limited runs. With amortization figured as 14 years (average actual life of a gas truck) and average power and maintenance costs, the electric truck breaks even with the gas truck in the fourth year and pays a dividend in lower costs in each succeeding year. The real life of an electric is not very well known. There are 70 of them in operation for United Parcel Service in Manhattan — the last of these built around 1930. Two veteran 14-ton electrics are still hauling paper for a publisher in Philadelphia, though their nameplates bear the date 1912!

Battery power has become well established for industrial trucks (lift trucks) because of this performance. Its cost record is the reason that electrics are now showing up as golf carts and passenger cars.

Sound and vibration control — The control of sound and vibration has always been of some importance in special cases. The proverbial boiler factory, for example, worries industrial hygienists and insurance company actuaries — and has worried them for some years past. Intense noise such as that from some industrial operations is a hazard to health and well being. Today, however, two emerging factors have broadened the scope of noise control as practical undertaking by a factor of perhaps a hundred. One of these is an increasing dependence on mechanical power and gadgets that make noise. Does your home have a radio, telephone, TV, dishwasher, washer-drier? All of these make noise whether it is enough to disturb a neighbor or only enough to disturb your reading or sleep. The second factor is the economic paring of all sorts of products to the minimum amount of material. Typical examples here are the use of lighter gauges of metal, the use of "dry wall" construction instead of plaster, etc. As our homes and cars and even gadgets become less massive, they lose their ability to stop noise from reaching our ears.

Lead possesses precisely the right properties to stop the transmission of sound. It has high density. It has low stiffness. Because of its mass it is very difficult for sound waves to set a lead diaphragm in motion. Because it is acoustically "limp" the lead diaphragm will not resonate or ring. In practice this means that 1/16 inch of lead has the same sound stopping power as 2 inches of sand plaster. A well-built plastered wall 4 inches thick affords no more privacy than that achieved by 1/8 inch of lead. With cost per square foot of floor space increasing, these figures interest architects and designers.

Sheet lead, laminated to other building materials (wood, gypsum lath, etc.) is being used in critical sound areas like broadcasting studios. Sheet lead is being applied to remedy bad sound transmission situations

Among the newer materials for sound control are the leaded plastics. Here the mass of powdered lead is combined with the limpness of sheet vinyl, for example, to achieve excellent sound stopping power in minimum volume and provide an attractive and easily worked material. At the pressure reduction station of one large gas pipeline here in New Jersey, upstream pressure of 150 psi is cut to 3, 5, 15, 25, 30, or 50 psi (depending on service requirements) by throttling control valves. In effect this arrangement is something like a giant factory whistle which must operate round the clock. Sound levels of over 130 decibels were recorded near the equipment. Industrial hygienists have set 120 decibels at the danger mark for anything more than very short short term exposure. By wrapping these pipes and valves with 1 1/2 inch fine filament glass wool bats and covering the glass with a single layer of leaded vinyl weighing less than one pound per square foot, the noise level had been dropped to about 80 to 100 decibels and far lower in the dangerous higher frequencies. In other words, the reduction shed had been a place that workers avoided before this treatment. The noise was literally nerve wracking. Today it is just one more building in the plant. A bit noisy, but not so bad that a conversation can't be held without shouting. It is no longer a halth hazard.

Leaded plastics also provide a great deal of damping for structures that do tend to resonate or ring. Even a light coating of about 2 ounces per square foot of finely powdered lead or lead ore in a soft plastic can be applied like paint to sheet steel so that it's "boinggg" is deadened. Heavier coatings, trowelled or cast on, or cemented on like tile, completely deaden it.

Where more intense vibrations are encountered — machinery mounts and building foundations, for example — pads made of layers of asbestos and lead have been serving successfully for half a century. Buildings such as the new Philharmonic Hall at Lincoln Center rest on these pads so that vibration from city subways cannot interfere with performances. Buildings in Canada, Boston, Texas, Buffalo, New York and other cities have been making use of the pads and the practice is becoming more widespread.

As this is being written, the N. S. Savannah is voyaging round the world. Five hundred and thirty odd tons of lead keep the atomic energy of the Savannah confined to her boilers and propulsion system. Bids have been solicited for a similar vessel for Germany.

Recently another 350 tons of lead were laid as a lubricating seal for the concrete walls of two water conduits of the Niagara Power Project. These conduits, or tunnels, are each over four miles long. They are sixty feet high; forty feet wide. And their massive cast concrete walls must seal tightly to the concrete supporting floor yet be free to "give" or slide slightly under earth shock or settling. How would you achieve that sort of seal? The designers did by laying a 1/16-inch sheet of lead two feet wide and casting the walls on top of this.

Thousands of tons of lead are being used in shipping containers for radioisotopes and spent fuels. It is employed as shielding in "hot" laboratories and in instruments with radioactive sources used in many industries. It encases delicate instruments in space rockets.

Lead compounds are the basis of the best porcelain enamels developed for aluminum. This is a new product that is gaining rapid acceptance for building facades, signs, subway cars and use on ships. The trend is also to lower firing temperatures in porcelain enameling steel and many of these lower temperature enamels also contain lead.

Brightly colored glazed bricks are becoming popular with architects for modern decorative constructions. Lead compounds have been found to be important ingredients of the glazes best suited to this purpose. Other new architectural products are color-backed glass blocks and flat glass wall panels. The color enamel applied to both of these products contains a high percentage of lead compounds.

Impressed current non-sacrificial lead anodes are being used on both commercial and naval ships. Lead's properties as a superconductor are being employed in some of the most modern computing devices.

Free-machining leaded steels have been familiar to industry for some time but now this material is available for forgings and in sheet, plate and tubular form. More than twenty companies are now marketing leaded steels.

A lead-base brazing alloy for low temperature metal to glass bonds has recently been developed and is finding commercial applications. A recent patent covers the use of lead in producing high purity titanium.

Special pearlescent lead pigments are finding wide and greatly varied commercial application. For example, they are used on theater movie screens and screens for home projection to improve the quality of the projected images. Other applications involved reproduction of the effect of pearl or mother-of-pearl on such items as buttons, costume jewelry, artificial flowers, cigarette boxes, toilet seats, and custom finishes for automobiles. New lead pigments for general painting use on both wood and metal are also recent developments that make available the advantages of lead at lower cost.

A low loss ceramic insulator body has been developed and patented which contains a high lead glass phase. High performance capacitors for use up to 500 deg. F. include 17 per cent of lead titanate. Lead-bearing glass capacitors for operation up to 300 deg. C. are said to be suitable for missiles and aircraft.

Many more new developments in lead could be cited, but these certainly suffice to demonstrate that lead is a twentieth century engineering material. These are just a few examples of the exciting future possibilities of lead. They are by no means all. Now to get to the more mundane but a highly important part of the story of lead, its production, fabrication and uses.

Almost 60 per cent of the lead consumed each year in America is used in its metallic form, either pure or as a principal alloying ingredient with a variety of other metals. How it is used and where it goes in industry are described briefly below.

Historical Background — Because of the ease of reduction from its ores, lead was one of the first metals used by man. Lead pipe manufactured by curving sheet lead together and soldering the seam was used by the early Romans for conducting drinking water. Architecturally, lead served as a roofing material for public buildings and churches. The famous dome of St. Sophia in Istanbul is lead covered. The floors of the Hanging Gardens of Babylon were lead covered to retain the moisture necessary for the vegetation. Lead was used in the construction of the first commercial sulphuric acid chambers plant built in 1746 in England.

Production — Lead is mined primarily as the sulphide (galena), the bulk of the domestic ore coming from southeastern Missouri and the Northwestern States. Lead, zinc and silver ores are usually found in the same deposits. After mining, the ore mixture is crushed and ground to fine powder and separated by the flotation process.

Lead is recovered by smelting in a blast furnace. A lead blast furnace is similar to an iron blast furnace but constructed on a smaller scale and, of course, operates at lower temperatures. Ore, coke and limestone constitute the normal furnace charge. Oxygen-enriched blast is one of the latest developments in lead smelting.

Lead bullion or unrefined lead containing other metallic constituents is normally "fire refined," that is, it is heated in large kettles under controlled conditions to remove and usually recover silver, gold, copper, zinc and some other metals. For example, gold and silver are recovered by taking advantage of the fact that these two metals have a greater affinity for zinc than for lead. By deliberately adding zinc to lead bullion containing gold and silver, these two valuable elements form a zinc-silver-gold mixture which subsequently floats to the top of the bath and is removed by skimming. Any zinc remaining in the lead is removed by creating a vacuum over the molten metal so that the zinc vaporizes and condenses as crystals on the cold top of the vacuum dome. The latter technique has been recently perfected and is known as the Vacuum Dezincing Process.

Collapsible tubes for toothpaste, shaving cream, colors-in-oil, etc. are often made of lead. They are formed by a process known as impact extrusion in which a button containing enough material for one tube is struck and forced to flow around a tube-shaped die. By using a button having a thin layer of tin on one side, a lead tube can be produced with one side tin coated. This system is used where bright appearance or corrosion resistance is required.

Because of its low melting point, lead is relatively easy to join by welding. For this process, oxyhydrogen is used with a very small burner tip. Joining lead to lead in this manner without solder is known in the trade as "lead burning." Actually a misnomer, the lead is not burned but merely fused together.

Soldering is a process familiar to everyone and solders of the tin-lead alloy systems constitute the largest portion of all solders in use. They are used for joining most metals. As given in ASTM Specification B-32-58T - Solder Metal, the alloys range all the way from 1 per cent to 70 per cent tin, the balance lead, each designed for areas of specific applications. An important property of these solders is the so-called pasty range useful in many applications. This pasty range is that area between the solidus and liquidus and varies with the alloy. For example, the eutectic alloy 62 tin, 38 lead, has no pasty range while the 20 tin, 80 lead has a pasty range of roughly 175 deg. F.

Common applications in which this pasty range or area in which the solder can be worked is important are in the application of automobile body solder (10, 15 or 20 per cent tin, balance lead) to fill joints and dents and the making of wiped joints (35 or 40 per cent tin, balance lead) in cable and in lead pipe.

The ternary alloy, tin, antimony-lead, is useful in many applications and may normally be used for the same applications as the binary alloy with the exception that their use is not recommended on aluminum or zinc or zinc-coated metals, such as galvanized iron. The addition of antimony up to 6 per cent of the tin content increases the mechanical properties of the solder with but slight impairment to the soldering characteristics.

<u>Why Lead is Used in the Chemical Industry</u> — Lead has played an important role in the chemical industry since the time when chemical engineering was practiced by the alchemist. The chief reason for its use is lead's (1) excellent corrosion resistance, especially to sulphuric acid from dilute up to 96 per cent acid. In addition to sulphuric acid, lead is noted for its resistance to phosphoric, chromic and hydrofluoric acids, and salts of most of these chemicals as well as sulphur dioxide and other corrosive gases.

Another reason for lead's use in the chemical industry is its (2) low cost compared to other corrosion resistant materials. Adding to its economic advantage is that (3) it can be salvaged easily and (4) has a high scrap value (as much as 75 per cent of the original cost). Once installed (5) the ease with which lead may be repaired also adds to its appeal.

<u>How Lead is Used As A Material of Chemical Construction</u> — Lead is naturally soft and although occasionally used alone, more often it is supported by an external framework of wood or steel. Frequently, steel or wooden vessels are lined with loose sheet lead fastened at intervals with lead covered steel straps.

A relatively newer method of joining vessels with lead is to bond the lead directly to the shell of the steel vessel. This is known as bonded lead lining or lead cladding. The bond may be accomplished by means of a very thin solder film between the lead and the steel, or by bonding the lead directly to the steel.

The direct bond is usually accomplished by first preparing the surface of the steel vessel by shot blasting or pickling, and then fluxing with molten zincammonium cloride, stannous chloride or certain proprietary fluxes. The lead is then melted and bonded to the steel by hand using lead burning bars and torches or it is poured on in large sheets at a time. Excess metal may be scraped off or "washed" off with broom-like torches. While somewhat more expensive as a result of the labor involved, bonded lead lined vessels are finding wider acceptance in industry today because by this method, the corrosion resistance of lead can be combined with the greater physical strength of the steel shell. High vacuum and higher operating temperatures which are more prevalent in industry today require this type of lining.

In many processes, lead pipe coils inside the vessel are used for cooling and occasionally for heating with steam or hot water. For use with steam pressures exceeding 50 and up to 150 lb. steam pressure, lead covered copper coils are preferred. Here again, as in a bonded lining, the greater strength and heat transfer characteristics of copper are combined with the corrosion resistance of lead.

Lead pipe and conduits are used widely for conducting corrosive liquids and fumes. Where the lead pipe is suspended, it is common practice either to lay it in a trough or use lead lined cast iron or steel pipe. The latter consists of ordinary pipe in which is placed a lead pipe expanded by hydraulic pressure to fit snugly.

<u>Lead in Plumbing</u> — Lead for many years has been used in household and industrial plumbing. It is used to conduct drinking water from the cast iron water mains in the street to the house. Inside the house, it is used in the form of pipe for wastes, lead traps beneath basins, tubs and showers, lead bends on water closets and occasionally as vent pipe. In practically all cases, the lead pipe is joined by wiping.

A surprisingly large amount of lead is also used in conjunction with cast iron water mains and soil pipe which are used to conduct waste to the sewer or for venting purposes. Here it serves as a calking material to form a water-tight seal between the sections of pipe. Usually the lead is melted and poured into the joint and then calked with special tools. Sometimes if it is impractical to use molten lead, as under very moist conditions, lead wool is used instead. Because of its self-weldability, lead wool is easily consolidated or calked into a solid waterproof mass.

<u>Architecture Applications</u> — Architecturally, lead also sees considerable service, most prominently as a roofing and flashing material. Here, its corrosion resistance, pleasing gray color and the non-staining feature of run-off waters are the chief advantages. It is also used for gutters, chimney caps, planting box linings, statues, spandrels, leaded glass windows and other ornamental devices. Lead coated copper is occasionally used for roofing and flashing purposes.

Lead is used for anchoring objects to masonry. Lead anchor bolts are available which have cast lead plugs as an integral part. When the bolt is tightened, it expands the lead inside the masonry and thereby forms a secure anchor.

<u>Lead Coatings</u> -- A number of objects are coated with lead containing less than 3 per cent tin, plus some silver and antimony by the process known as "hot dipping". This is somewhat similar to hot dip galvanizing. Terne plate is used quite extensively in industry. It is made in the same manner as tin plate except that instead

of pure tin, an alloy of lead and 15 to 25 per cent of tin is used. Large quantities of sheet steel are terne plated and used in making paint cans, gasoline tanks for automobiles and other metallic containers requiring corrosion resistance. Objects made by deep-drawing sheet steel use terne plate because lead's lubricating characteristics facilitate the drawing operation.

In salt water service, lead and lead-tin alloys are used for resistance to both static and fast-flowing aerated sea water. In the latter case, alloys containing increasing amounts of tin with the maximum at 40 per cent afford satisfactory protection. For example, as applied by hot dipping or wiping, lead-tin coatings are used as protection for copper in shipboard circulating systems. In hot dipping, because of alloying with copper, the resultant alloy or coating is cathodic to copper and attack by electrochemical and galvanic action may be encountered at pinholes. In wiped coatings, alloying occurs but it involves only a thin layer which is covered by a dense anodic lead-tin layer.

Lead may also be applied by plating when justifiable cost-wise. Where large build-up is required, for instance, this technique becomes feasible.

Electrical Applications — In the electrical industry, the chief use for lead and also the greatest consumer of lead is the storage battery. Storage batteries contain on the average, 25 lb. of recoverable lead. This includes both the lead alloy used for making grids as well as the lead oxides used on the battery plates.

Also in the top third of the lead consuming industries is the manufacture of cable sheathing. A sheath for cable, whether telephone or power, must be (1) corrosion resistant and impervious to the atmosphere and soil water, (2) flexible enough to be coiled on reels and drawn through conduits and (3) it must be able to be extruded to form a continous sheath around the wires in a cable.

In certain applications, copper wire is coated with lead before being covered with rubber insulation because the sulphur compounds in some rubbers attack copper and vice versa, copper affects some insulating materials adversely. The presence of a lead coating eliminates any reaction between the copper and rubber.

Although by no means large, unheralded electronic features account for lead's use in intrinsic semi-conductors such as lead telluride. In some cases, this material is modified by the addition of elemental lead for improved conduction.

Why Lead is Used in the Plating Industry — In the plating industry, particularly chromium, copper and nickel plating, lead is used as a tank lining material, as an anode, and for heating coils. It is used for two reasons here. (1) because lead is normally resistant to attack from the acid electrolytes used in plating these metals and (2) because any corrosion products that might be formed do not affect the plating operation or the final appearance of the plate. A more recent development in this industry is the anodizing process in which a cold sulphuric acid electrolyte is used. Lead or lead covered copper coils are used to cool the anodizing solutions by means of circulating brine or freon and the tanks themselves are lead lined.

Heat Treating Baths — Lead is used in many steel heat treating operations instead of molten salts because (1) it can be operated at higher temperatures without fuming (up to about 1300 deg. F.), (2) it does not absorb moisture, (3) it does not erode the metal being treated, and (4) it has good heat transfer characteristics.

Bearings — Most freight cars run on bearings consisting of a layer of lead-tin-antimony alloy supported by a bronze shell (80 copper- 10 tin- 10 lead).

Lead base bearing metals offer high resistance to compression yet are soft enough to prevent wear of the more costly and hard to replace axle. They possess the plasticity necessary to absorb foreign particles which normally would score the shaft. When the bearings have served their useful like, their high scrap value makes for economic replacement. Lead base bearing metals also conform and adjust automatically to slight irregularities in the machining and alignment of the shaft.

Copper-lead bearings are used in automobiles. Composite bearings consisting of thin lead babbitt on a matrix of copper and nickel powders sintered on a steel backing have been used in automobiles. An average of 2 to 4 per cent lead powder is used in sintered metal powder bearings of the self-lubricating type.

Radiation Protection — Lead is used universally for protecting patients and operating personnel from harmful exposure to x-rays and gamma rays emitted by Coolidge tubes, betatrons, and radium, as well as cobalt 60, tantalum 182, and other radioisotopes. Lead itself does not become radioactive on exposure to these rays and hence can be used as long as required and moved to other locations without fear of radioactive contamination.

For very large atomic energy installations, particularly those being designed from the ground up, shielding is accomplished by using thick concrete walls often sandwiched with relatively thin sheets of lead. Probably the bulk of the lead used for protection against atomic radiation is in the form of cast lead shipping containers and bricks about the size of common building bricks. Using lead bricks, barriers can be constructed in practically any location and to protect against any degree of radiation.

Other Uses — Because of its excellent thermodynamic properties, lead in the fused state is used in atomic reactor heat exchange systems. In addition, fused lead and lead alloys are used as suspension fluids for ultra-sensitive gyros.

How Much Lead is Used — How many tons of lead are actually consumed by American Industry in a year? In 1959, this figure was just over 1,000,000 tons, slightly below average. The average consumption for the five years prior to 1959 was about 1,150,000 tons. In 1958 we produced from our own mines about 260,000 tons and roughly 480,000 tons were recovered from secondary sources such as old storage batteries and cable sheathing. From this it is obvious that this country consumes more lead each year than it produces. To account for this, 310,000 tons were imported from the rest of the world with the bulk of these imports coming from Mexico, Canada and South America, with about a third coming from overseas sources. The difference between consumption and production is made up of changes in stock and government stockpiling.

Where Does It Go — The biggest consumers are the manufacturers of storage batteries. Next are the manufacturers of tetraethyl lead. Third and fourth are cable sheathing and construction.

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Future Outlook — Despite predictions made twenty years ago that we would have no lead today, lead is still plentiful and its continuing supply is assured for many years to come. New mines have been opened and most of the old ones have not as yet hit bottom.

Lead is fortunate among the metals in that the bulk of its uses are recurring that is, after being used, it can be salvaged and returned to the market as secondary metal ready for reuse. Storage batteries and cable sheathing, two of the larger consumers of lead are typical examples of recurring uses.

As an engineering material, lead's characteristics are so diverse that as old uses dimish, new ones such as those described earlier are developed. In addition, new alloys having improved properties have enhanced the use of lead for many old applications and have fostered the development of many new applications.

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Lead Industries Association is always willing to cooperate without obligation in the solution of problems involving lead. Inquiries should be addressed to 292 Madison Avenue, New York 17, New York