

The position of lead in a challenging world of modern technology

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THE old appellations of lead—'enduring metal' and 'indestructible metal'—were originally meant to signify its excellent corrosion resistance and the endless cycles in which the metal was used, scrapped and re-used. These attributes appear to be even more appropriate in the present day challenging world of modern technology. With the advent of modern metals and synthetic materials, it was feared that lead might go gradually out of usage. On the contrary, the consumption of lead has been steadily increasing from ancient times and does not show any sign of levelling off. However, its growth rate has not been so spectacular as, for instance, the modern metal aluminium. There have also been numerous inroads into many of the applications of lead; nevertheless, not only the traditional and relatively old and established uses of lead are being continued, several new and modern uses of lead have been invented so that lead will continue to be used in ever increasing tonnages in the future.

The success of lead has been due to its relatively low price (it is the cheapest non-ferrous metal) and the unique combination of mechanical and chemical properties and no other metal is used in so many diverse applications. Lead seems to have an inexhaustible range of versatile properties. Some of these apparently latent properties are being continuously unearthed and appreciated, with the result that the metal is being put to new uses and applications in the ever changing and demanding conditions of modern technology. For instance, lead has always had the property of sound attenuation and shielding for radioactive rays. But these properties came to the fore only recently in the twentieth century. Likewise, there are ever so many properties of lead that lie hidden in its many compounds and these are being discovered slowly and steadily, finding newer and more exotic applications for the ancient metal.

The story of lead has been remarkable in several respects. At a time when it had practically no competition from modern metals and synthetic materials, its growth rate was relatively slow. For example, during the whole of the 19th century, lead consumption was only of the same order of magnitude as that consumed

SYNOPSIS

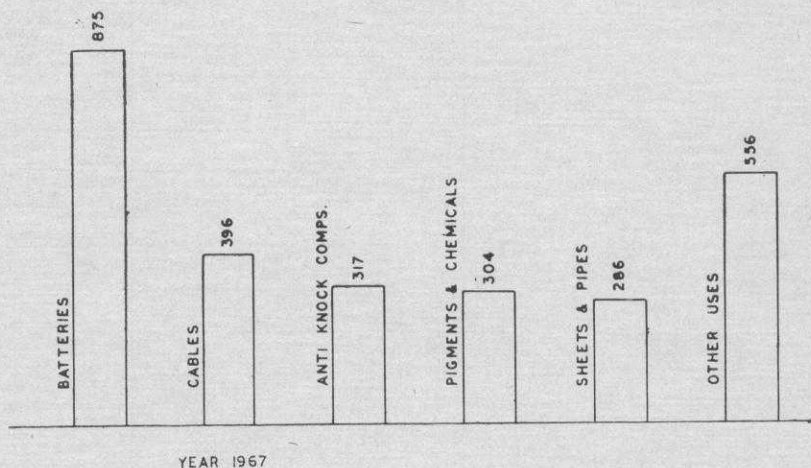
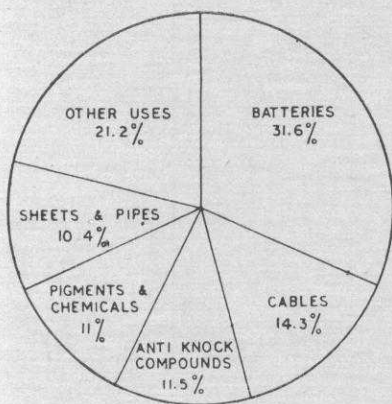
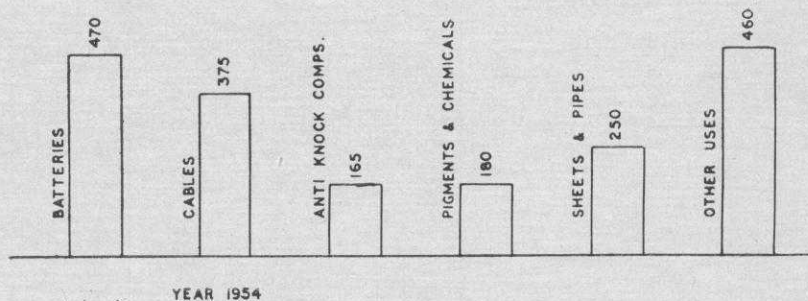
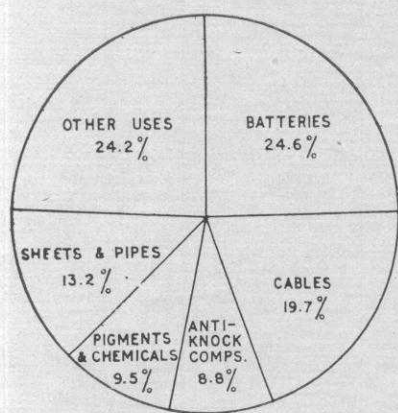
The old appellations of lead such as 'enduring metal', 'indestructible metal', etc. appear to be even more appropriate in the present day challenging world of modern technology. The unique combination of diverse properties of lead has helped in the steady growth and usage of this ancient metal in spite of severe competition from newer metals and materials. The paper describes the traditional uses of lead, the change in pattern of consumption due to the changes in the modern world and the advent of other materials. It also describes the more modern uses of the metal and predicts a steady increase in the consumption of lead for newer and better applications.

during the whole 20-year period between the great wars. Subsequent growth rate was much faster and in the last ten years the world has used more lead than that used during the entire twenty-year period between the wars. The growth in consumption of lead in the past decade has been showing a steady upward trend. This has been possible by not only the world using more tonnages of lead in the established applications of the metal, but also due to new uses and applications.

Changing patterns of use

Lead has been in use for well over 2000 years. It was used in plumbing by the Egyptians, and some of these fixtures are preserved in good condition even today. Lead continues to be used in plumbing even in modern times and the traditional uses of lead in building are still being continued. There has, however, been marked changes in consumption over the century and particularly in recent times. Before the second world war, the main use of lead was cable sheathing, with sheet and pipe occupying the second place followed by pigments and then batteries. In the 50s, with the coming in of the automobile age, batteries moved to the second place, cable sheathing still maintaining the first place. Later, batteries became the biggest outlet, the cables being pushed down to a secondary place. The change in the pattern of world consumption of lead during 1954-67 is depicted in Fig. 1 which

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1 End-use pattern of world lead consumption in 1954 and 1967 ; figures are in '000 tonnes

shows that there has been a considerable increase in the total tonnages of lead used in all its applications while the use of lead in batteries and anti-knock compounds has registered a significant rise.

Established uses of lead

The established uses of lead are in batteries, cables, pigments and sheet and pipes. These will be dealt with briefly, outlining the recent modern developments.

Lead-acid batteries

Batteries comprise the major outlet for lead and, with no chance of any competition in this field, consumption of lead through this application is bound to show a significant upward trend in proportion to the increase in the number of vehicles manufactured. The varieties of batteries in use today consist of three categories : SLI batteries for starting, lighting and ignition and

similar small batteries used in aircraft and trains ; traction batteries for industrial trucks and commercial road vehicles ; and, stationary batteries to provide emergency or auxiliary power in hospitals, theatres, telephone exchanges and power stations. In addition, there are other minor uses, such as for portable appliances, television sets, etc. A steady growth is expected in all of these applications. In the last couple of years or so, considerable interest has been shown in the revival of battery powered passenger cars. Already, traction batteries are used in delivery trucks and other industrial vehicles and railcars, as for instance, in Germany. Although the battery-operated passenger cars have a drawback in a limited mileage range, there are numerous advantages such as absence of noise and smoke, lower running and operating costs, safety and reliability. These, together with a change in the living conditions of the modern world, make the battery vehicles attractive in spite of their handicap of limited range.

Although the lead-acid battery has had no serious

competitor, the battery manufacturers have never been complacent and have spared no pains for the improvement of their product. The modern version of the battery is a great improvement on the earlier product. Batteries are much lighter today, pack more power and give longer lives. Most of the improvements in the battery can be attributed to the rapid advances made in automobile technology and the exacting demands made by the automobile manufacturers. With the battery powered passenger car on the threshold of development, there is a demand for even lighter and more powerful batteries. Battery manufacturers are relentlessly trying to improve their products. On the metallurgical side, they are trying to develop dispersion-strengthened lead which holds promise as a material for battery plates. Similar research is going on for developing lighter containers, better separators and so on.

Cable sheathing

Lead is the most preferred sheathing material for power cables in the medium voltage range. There is no likelihood of changes in the position of lead and this is indicated by the installation of a large number of new continuous lead extruders throughout the world in recent years.

In the lower range of voltages up to 1 KVA, there has been extensive substitution by plastics and in the higher ranges (gas and oil-filled) there has been some substitution by aluminium. Lead is still preferred where utmost reliability is required and, wherever substitution has taken place, it has been predominantly for economic rather than technical reasons. No further large scale substitution of lead is likely to take place in the near future. Furthermore, research and development work in progress for thinner and stronger lead-sheathing may counteract the trend for substitution. The ultimate solution perhaps may lie in the joint use of materials such as lead and plastics. As of now, dispersion strengthened lead seems to be a promising material.

Sheet and pipes

About 300 000 tons of lead are being used for the manufacture of sheet and pipes for the building and chemical industry. Although the gross tonnage used in this application is much more now than it was a decade ago, lead is facing stiff competition from other metals, notably from plastics. Lead laminates may find increasing use in the chemical industry if the tests now in progress to assess the effectiveness of the adhesion bonding techniques (to replace older methods of lead burning) for lining steel acid tanks, etc. prove successful. Dispersion strengthened lead is now used in chemical plant with considerable success.

Pigments and alloys

While white lead has lost a significant portion of its market to titanium dioxide, red lead is holding

its own as heavy duty structural primer. The main competitors to lead pigments in primers for iron and steel are iron oxide, zinc dust and zinc chromate, but paints based on them require a much more thorough surface preparation, though they may have some compensating advantages.

Lead alloys are extensively used in solders, printing metals and bearings. There are different kinds of solders, depending on the industry. The automobile industry today uses solders to connect the contours of pressings and other type of solders for radiator manufacture. There seems to be no threat of substitution of lead in both these applications, although there is an indirect threat to this outlet in the development of aluminium radiators. The use of solder in making cans from tinplate is nowadays confined to the side seams, the end seams being sealed with 'lining compounds'. There is a trend towards reducing the amount of solder per can and the tin content of the solder. Unalloyed lead has, in fact, given satisfactory results. However, there is also a move to dispense altogether with side-seam soldering, although it is doubtful if the use of sealing compounds and other techniques can cope with the high speed of manufacture of the order of 500 cans per minute.

No significant changes in lead consumption in the form of solders are expected in the electric and electronic industries. The introduction of printed circuits has not brought about a reduction in solder consumption, but the current trend towards micro-miniaturisation (solid state circuits) may reduce the consumption of solder by the electronic industry at some time in the future.

With changes in printing methods leading to a progressive replacement of hot metal techniques, the demand for printing metal is likely to fall. Trends of lead consumption in bearing alloys are not very clear. There have been some substitutions in several types of bearings, but the overall demand is still good, although likely to fall in the future.

Lead sheets, collapsible tubes, etc.

Lead sheets, collapsible tubes, etc. are minor outlets for lead. The former is expected to grow steadily while the latter, which has lost a significant portion of its market to aluminium, has regained some of the lost ground in respect of fluoride toothpastes where aluminium cannot be used.

Modern uses of lead and recent research and development

Having discussed the traditional and established uses of lead, an attempt will now be made to review briefly the modern uses of lead and recent research and development.

Organolead compounds

Tetraethyl lead and tetramethyl lead (the anti-knock compounds) are the most well-known organolead com-

pounds, accounting for about 250 000 tons of lead a year. With the rising consumption of petrol and the increasing use of automobiles, there will be a growing demand for the lead anti-knock compounds. In recent years, under the active research programme of International Lead Zinc Research Organization (ILZRO), several new organolead compounds have been synthesised on a semi-technical scale and are under assessment by the industry in a number of potential uses. All these will develop new markets in such diverse applications as antifouling paints, wood preservatives, lubricant additives, anti-bacterial agents, molluscides for the control of bilharzia disease, rodent repellants, polyurethane foam catalysts and rot-resistant textiles.

Noise and vibration control

Lead, both as sheet metal and as a component of fabricated composite materials, is finding increasing use in sound and vibration control. The normally undesirable properties of heavy weight and bulkiness cause the most ideally suitable combination of properties required for acting as a barrier to air-borne noise. In spite of the heavy weight of lead, it is claimed that for an equally effective sound barrier condition, the partition built of lead will be almost invariably lighter. Although lead partitions are not as cheap as conventional building materials, the savings effected in extra usable space and lighter structural requirements, thinner floors, etc. may make them a more economical proposition, particularly where building space and weight are of importance.

Lead is also used as a dispersed powder in vinyl sheet, with or without fabric backings. Silicone and epoxy formulations loaded with powdered lead or lead ore are also used. Many new materials, chiefly plastics in vinyl epoxy and polyethylene-polypropylene families, have been used with lead and lead compounds to form new composites suited for special use. Lead laminates with other metals such as aluminium are used as enclosures to noisy machines to lessen sound transmission.

Lead and asbestos have been used in building to reduce the transmission of vibration. With the increased number of high speed and heavy vehicles, underground railways, air-conditioning and other machinery, it is necessary to employ anti-vibration or isolation materials more extensively. Lead by itself can be used for anti-vibration pads, since it has the blend of required properties—massive but not rigid. However, a combination of lead and asbestos has not only vastly superior anti-vibration properties (than either material alone) but has a number of other favourable characteristics, such as easy workability, corrosion and chemical resistance, imperviousness (of lead) to water and, above all, very high load bearing capacity. Lead-asbestos is used extensively to reduce transmission of vibration due to railroad or sub-way traffic from the ground to adjoining building structures. A recent trend has been the isolation of vibration from big and small machines which are located inside or on top of buildings, for example, cooling towers.

Lead in ceramics

The use of lead compounds in the ceramic industry is not by any means new, but there have been remarkable achievements in this field in recent years. For instance, it has been possible to develop strongly adherent enamel coatings capable of withstanding repeated blows and resistant to chipping and cracking. Both functional and decorative effects can be achieved, such as in the enamel coating of aluminium which, in turn, has led to the production of enamel cast aluminium and magnesium. Porcelain enamelled aluminium laminated on hardboard and masonite can be sawed, sheared or drilled with simple tools and hence finds immense use in and around the home. The high lead content, low firing temperature enamel on steel may find increasing use in window frames, kitchen cabinets, etc. because of the ease and versatility of application.

Lead in thermoelectricity and piezoelectricity

Although thermoelectric power is available at relatively low conversion efficiencies, it has some unique advantages and great commercial potential. The possibility of its use as a remote power source with relatively light weight and no moving parts holds attraction in a variety of applications. In spite of every energetic research for newer and better materials, lead telluride is the most efficient material for power generation in the range of 260 to 650°C. Its scope of application is two-fold—firstly, as an auxiliary power from waste heat sources; secondly, as independent power packages for areas remote from power lines. Lead-telluride is being used increasingly in thermocouples in some industrial and home control systems because it provides relatively greater power and has made it possible to dispense with expensive amplifying mechanisms or secondary power sources to drive controls. Called PZT in the trade, a mixture of lead-zirconate and lead-titanate is an excellent piezoelectric material and has great commercial potential. Its introduction in ultrasonic cleaning and processing equipment may make this process more widely accepted. It is used in 'spark pumps' (tiny gadgets accommodated in the palm of a hand and capable of generating a 20000 volt spark) which form part of the starter mechanism of lawn mowers and other machines.

Lead coatings

Terne plate is not really a modern material. But there has been a revival of interest in this material, particularly in the U.S.A., not so much due to any developments in the process or product, but due to the availability of the product in more suitable forms. Terne plate is currently used for roofing, automobile and other gasoline tanks, radio and television chassis, non-food cans and a variety of miscellaneous metal products in which corrosion resistance, deep drawing and solderability are important.

ILZRO has developed a high speed electroplating technique for lead and lead alloys, and electro-terne

is now well on its way to acceptance on a commercial basis. One important application will be in the automobile industry. Other applications include non-food cans, metal house siding and roof drainage products.

D. M. Machine

In acoustical and roofing applications, although lead is an ideal material, it is still considered expensive, and the exclusive application of lead for this usage will depend on the low cost of lead sheet. Significant achievements have been made in this direction by the invention of the machine for continuous casting of lead sheet. It is claimed that the total cost of casting a thin gauge sheet by this process is less than one fifth of the cost by conventional rolling techniques. This development will be an essential part of the ultimate success of many of the applications of metallic lead sheet.

Dispersion strengthened lead

Research and development work on the powder metal-

lurgy of lead promises to yield very high dividends in the form of several new products which will be considerably superior to the lead and lead products available at present. Rolled and extruded products of lead, obtained from powders, can be considerably strengthened by the introduction on their surface of a thin layer of oxide. The material has great potential application in the manufacture of batter grids, roofings and cable sheathing.

Conclusion

Lead is perhaps used in more diverse applications than any other non-ferrous metal and, in a short article, it is not possible to do full justice to the numerous uses of lead and its compounds. Lead is a very ancient metal but has not only survived the vicissitudes in technology but also continues to perform important functions in home and industry. Relentless research on lead for new products and improvement of old products and processes are continually in progress, and it is predicted that lead will continue to be used in ever increasing tonnages in the future.

Discussions

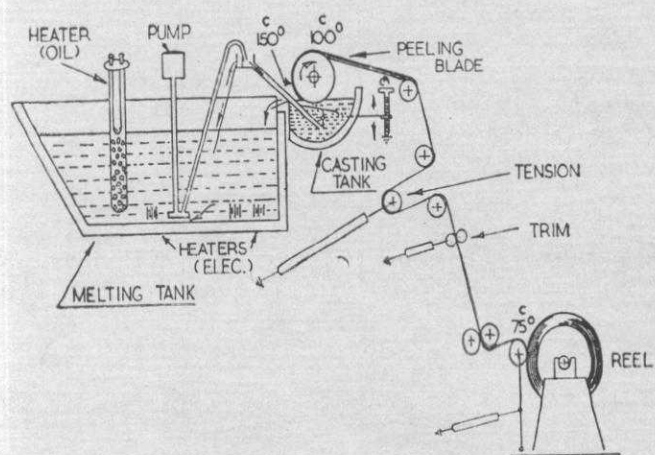
Dr L. Wallace Coffey (Operation Hardrock, New Delhi) : Could you tell us a little more about the direct formation of sheet from molten lead ?

Dr M. N. Parthasarathi (Author) : The process of continuous casting of lead sheets is popularly known as the DM (Direct Manufacturing) process. A water-cooled drum or roll just dips in a bath of molten lead and is rotated at a pre-determined speed. As the molten metal comes in contact with the drum, it solidifies in the form of a sheet and is carried forward by the rotating drum. The sheet is then stripped by means of a blade known as the doctor blade and then trimmed and coiled on to a reel. Figure shows a schematic diagram of the DM machine. The sheet thickness would depend on such factors as temperature of the molten lead, rate of heat extraction from the drum, speed of rotation of the drum, depth of immersion of the drum in the bath, etc. The machine for this DM process is relatively simple in construction and provides a fully integrated production unit

with low cost of installation and operation. At present the DM process is suited to pure lead or lead alloys having a narrow solidification range and research work is being directed towards further development of the process to increase its range of applicability.

Mr G. Rama Rao, (Barauni Oil Refinery) : Lead is used nowadays for the storage of radioactive isotopes ; what property of lead has been taken into account in this case ? Is it density alone or some other aspect ?

Dr M. N. Parthasarathi (Author) : While the major reason for using lead as a radiation shielding material is its high density or massiveness, there are certain other factors which also favour the use of lead for this application. Lead has the important advantage in that it does not become a source of secondary radiation. Lead radiation shields almost invariably result in saving in weight and space. There are instances where the use of lead instead of iron for gamma radiation attenuation has resulted in a weight



1 A schematic diagram of the direct manufacturing lead sheet casting machine

saving of at least 30%. This corresponds to a shielding thickness reduction of more than 50%. In general, lead radiation shields are also easier to handle and install.

Mr Sunil Dey (Chemical and Metallurgical Design Co. (P) Limited, New Delhi): Will the author comment on the advantages and disadvantages of homogeneous lead lining with/without tinning?

Dr M. N. Parthasarathi: Homogeneous lead coating is, from the technical point of view, the most perfect of the lead coating processes because it combines the strength of the steel with the corrosion resistance of the lead. Generally a tin solder is used as a bonding material between lead and steel. The tin solder melts on deposition of the lead and diffuses into it. While tinning gives rise to a very strong bond between lead and steel, there is however a disadvantage in that at higher temperatures and higher acid concentrations, corrosion might result due to the diffusion of tin into lead. Corrosion tests with various types of lead coatings of varying tin contents in the presence of sulphuric acid showed that the attack was proportional to the tin content. Tests have shown that in

carrying out homogeneous lead lining, as little tin as possible should be used. Of particular importance are homogeneous lead coatings which are exposed to high chemical or thermal strains. Experience has shown that tinless lead coatings perform satisfactorily at high temperatures and high acid concentrations.

While it is acknowledged that the use of tin results in a very strong bond between lead and steel, it must be however kept in mind that to ensure a safety margin, tin soldered homogeneous lead coatings should not be employed at a temperature higher than 180°C. On the other hand, tin-free coatings can be heated up to 220°C with no danger of the lead coating getting detached.

Mr S. W. K. Morgan (Imperial Smelting Process Ltd., England): What are the uses of dispersion strengthened lead in batteries?

Mr U. K. Chatterjee, (Indian Institute of Technology, Kharagpur): What may be the specific uses of dispersion strengthened lead?

Dr M. N. Parthasarathi (Author): Dispersion strengthened lead has shown promise as an excellent material for fabricating battery grids. While the antimonial lead alloys which are being presently used have better strength than pure lead, they however have inferior electrochemical and corrosion properties. DSL, on the other hand, combines the excellent corrosion resistance of pure lead with the high mechanical strength of lead alloys. It, therefore, constitutes an ideal material for battery grids.

Dispersion strengthened lead can replace pure lead and lead alloys in all the traditional applications of this metal, and at the same time, it can be used in a number of new applications.

DSL has so far been tried out in such fields of application as lead acid batteries, cable sheathing, radiation shielding, sound attenuation, chemical plant construction and architecture.

Widespread application of DSL is possible on account of its good mechanical properties, excellent corrosion resistance and satisfactory electrical and electrochemical properties.